REPORT OF THE CHEMIST.

WASHINGTON, D. C., *January* 1, 1890.

SIR: I submit herewith the following abstract of the work done in the Chemical Division of the Department of Agriculture during the past year.

Respectfully,

H. W. WILEY,
Chemist.

Hon. J. M. RUSK,
Secretary.

The work of the Chemical Division during the past year has been of a varied character. There has been the usual amount of miscellaneous work, but a gratifying decrease in the quantity of assays for the precious metals which have been required of the chemists of the division. The attempt to break a long established custom, even if it be plainly *extra legem,* is very difficult, and there are still many demands made upon the chemists of the Department of Agriculture by members of Congress and other influential people for the assay of gold and silver ores, and examinations of mineral waters, and for other work having no relation to agricultural investigations, and for the exclusive benefit of the parties interested. It is hoped that gradually all such work may be refused and remanded to chemists who shall be employed especially for that purpose by the parties interested.

There is another class of analyses which has also made a less demand upon the time of the chemists of the division. I refer to the analyses of soils and fertilizers from different parts of the country. In all cases during the past year, save in a few exceptional ones, the persons asking for such analyses have been respectfully referred to the agricultural experiment stations of the States of which they were citizens. The experiment station is, without doubt, the proper place for such work to be done, and inasmuch as the General Government has given to each one of these stations substantial financial aid, it is only simple justice that this class of work be given to them. Although we have thus been relieved in part of the burden of routine work formerly imposed upon us, there has still been a large amount of miscellaneous work demanded, and the force of the Department has been unequal to keeping up with the work proposed. As a consequence of this the regular investigations of the division have been somewhat retarded on account of the necessity of permitting a part of the chemical force to engage in the miscellaneous work indicated.

ANALYSES OF FERTILIZERS.

Numerous analyses of fertilizers, fertilizing materials, clays and marls have been made in the division since our last report, but these appear to have only a local interest; and inasmuch as the results of the work have been sent by mail to the persons interested they are omitted from this report.

PRODUCTION OF BEET-SUGAR.

Since the report made in Bulletin No. 5, in 1885, on the production of beet-sugar in California, much interest has been manifested, not only in that State but in other parts of the United States, in the establishment of a beet-sugar industry. A large number of samples of beet seed was sent out by the Department last spring to different part of the United States, and we have received many samples of sugar beets for analysis as the result of this distribution.

These analyses are as follows:

From E. G. Church, Topeka, Kans., a sample of sugar beet with the following composition:

	Per cent.
Total solid matter	16.20
Sucrose	11.44

The low purity indicated by the above analysis is due doubtless to the fact that the beet had been harvested for a long time and had deteriorated somewhat from its original condition.

From A. H. Almy, Norwich, Conn., two samples of sugar beet, which on examination gave the following results:

No. 1.	Per cent.
Sucrose	3.87
Degree brix	8.60
Purity	41.00

No. 2.	Per cent.
Sucrose	7.90
Degree brix	12.30
Purity	64.23

These beets were very poor and unsuitable for the manufacture of sugar.

From the Empire Coal Company, Gilchrist, Ill., a sample of sugar beets of the following composition:

	Per cent.
Juice expressed	55.62
Total solids in juice	14.51
Sucrose in juice	11.30
Purity co-efficient	77.86

The above sample was of fair value for sugar-making purposes but not first-class quality. For the first year's experiment, however, it may be considered favorable.

From William M. Steer, West Branch, Iowa, a sample of sugar beets of the following composition:

	Per cent.
Juice expressed	58.74
Total solids	9.70
Sugar in juice	6.20
Purity co-efficient	63.91

These beets were of a very poor quality and unfit for sugar-making purposes. It is possible that the planting of the beets was too late and that they had not time to ripen.

From Ira Ford, Hastings, Nebr., of two samples of sugar beets which were analyzed with the following results:

No. 1, labelled A. F. Powers; soil, black sandy loam.

No. 2, labelled Lain's Imperial, grown by Fred Johnson; beets grown all in one row; the largest one weighed 6 pounds; planted April 23, 1889; harvested October 17, 1889; soil, black sandy loam.

	In the juice.	
	No. 1.	No. 2.
	Per cent.	*Per cent.*
Total solids	14.02	13.77
Sucrose	9.25	9.75
Purity co-efficient	65.90	70.80

From Gustav Onken, Chapin, Ill., four samples of beets, which on being analyzed gave the following results:

No. 1, six beets, raised by J. B. Kinnet, Chapin, Ill., on black prairie land; all beets grown in one row; plants at the distance of about 1 foot; no fertilizer used.

No. 2, seven beets, raised by B. H. Merrill, Chapin, Ill.; beets were raised in Scott County on barren timber land; no fertilizer used; plants all grown in one row, at a distance of about 1 foot apart.

No. 3, six beets, grown by Gustav Onken; planted the latter part of April, 12 inches apart each way; the beets were finally thinned until there were sixteen plants to the square yard; soil, black; no fertilizer was used; crop hoed four times.

No. 5, four beets, grown by Frank Burnham, on black soil; row 12 inches apart; no fertilizer used. There were about twelve plants on a square yard; the ground had been manured in 1888 in the spring, but not since then.

	In the juice.			
	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Total solids	12.17	14.02	7.62	11.32
Sucrose	8.40	9.50	4.05	7.10
Purity co-efficient	69.02	67.76	53.14	62.72

These beets are all of very poor quality, and not suitable for sugar making purposes.

From Harry F. Downs, Lincoln, Nebr., three samples of sugar beets, numbered 36, 34, and 40, which were analyzed with the following results:

No. 36, grown by Rollin Orcutt, Harmony, Nebr.; variety, Vilmorin; planted May 18, 1889; sandy loam soil; cultivated by the hoe; harvested October 10, 1889.

No. 34, grown by D. Windhusen, Pender, Nebr.; variety, Vilmorin; planted May 15, 1889; soil, black loam; cultivation same as for corn; harvested October 14, 1889.

No. 40, grown by A. S. Darling, Alliance, Nebr.; variety, Lane's Imperial; planted May 27, 1889; soil, black sandy loam; cultivation, plowing and hoeing; harvested October 21, 1889.

Analytical data.

	In the juice.		
	No. 36.	No. 34.	No. 40.
	Per cent.	*Per cent.*	*Per cent.*
Total solids	16.02	14.37	17.60
Sucrose	12.50	9.00	12.30
Purity co-efficient	78.02	62.63	69.88

From W. C. Buderus, Sturgis, S. Dak., four samples of sugar beets, analyzed with the following results:

No. 1 marked Alkali White.
No. 2 marked Sturgis White.
No. 3 marked Alkali Red.
No. 4 marked Bear Butte White.

Analytical data.

	In the juice.			
	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Total solids	16.20	14.87	19.37	22.25
Sucrose	10.75	8.50	13.55	17.00
Purity co-efficient	66.35	57.16	69.95	76.40

From the above analyses it is seen that Nos. 3 and 4 show beets having a very high content of sucrose, especially the latter, and capable of yielding a satisfactory amount of sugar if manufactured. The purity co-efficient of the samples is somewhat low, but this is doubtless due to the fact of the ground on which they were raised being fresh.

From Ira Ford, Hastings, Nebr., three samples of beets, analyzed with the following results:

No. 1, grown by Fred. Bates; light loam soil; variety, Lane's Imperial.

No. 2, grown by Fred. Rinker; soil, black sandy loam, an old clover pasture plowed in 1888; no manure; variety, Lane's Imperial; planted May 10; harvested October 25, 1889.

No. 3, grown by Fred. Bates; light loam soil; variety, Vilmorin.

Analytical data.

	In the juice.		
	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Total solids	8.90	17.07	14.20
Sucrose	6.00	12.50	10.20
Purity	67.41	73.22	71,80

From the above analysis it is seen that No. 2 contains a sufficient amount of sugar to make it valuable for manufacturing purposes. The other two fall below the standard, and No. 1 especially would be worthless for sugar-making. With such beets as No. 2 a yield of 150 pounds of sugar per ton could be reasonably expected.

From John Jenkins, Lincoln, Nebr., twelve samples of beets, which were examined with the following results:

No. 25, grown by Henry Nagle, Chicago, Nebr.; variety, Lane's Imperial; planted May 13; harvested October 10; soil, black sandy loam.

No. 27, grown by L. A. Gannon, Lodge Pole, Nebr.; variety, Vilmorin; planted April 27; harvested October 23; soil, dark sandy loam.

No. 35, grown by John Gabriel, Cedar Bluffs, Nebr.; variety, Vilmorin; planted May 25; harvested October 10; soil, black rich loam.

No. 38, grown by E. E. Adams, Mentorville, Nebr.; variety, Vilmorin; planted May 15; harvested October 10; soil, light sandy loam.

No. 39, grown by George M. Beor, Orleans, Nebr.; variety, Vilmorin; planted May 31; harvested October 18; soil, bottom land.

No. 41, grown by William Tweed, Bassett, Nebr.; variety, Vilmorin; planted May 25; harvested October 3; soil, sandy loam.

No. 43, grown by R. L. Grosvenor, Hoskins, Nebr.; variety, Vilmorin; planted May 25; harvested September 26; soil, sandy loam.

No. 46, grown by Edward Arnold, Odell, Nebr.; variety, Vilmorin; planted May 15; harvested October 26; soil, sandy loam.

No. 47, grown by Joseph B. Mourer, Aurora, Nebr.; variety, Vilmorin; planted June 1; harvested October 31; soil, light.

No. 49, grown by G. W. Alexander, Milligan, Nebr.; variety, Vilmorin; planted June 1; harvested October 25; soil, common prairie.

No. 51, grown by Joseph Lamb, Hubbell, Nebr.; variety, Vilmorin; planted May 23; harvested November 4; soil, black loam.

No. 48, grown by John Darr, Scottsville, Nebr.; variety, Lane's Imperial; planted May 28; harvested October 15; soil, sandy loam.

Analytical data.

	In the juice.					
	No. 25.	No. 27.	No. 35.	No. 38.	No. 39.	No. 41.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total solids	14.00	15.57	18.20	25.80	18.35	12.82
Sucrose	9.35	10.45	13.50	22.30	13.50	10.10
Purity	66.78	67.11	74.17	86.43	73.56	78.77

	In the juice.					
	No. 43.	No. 46.	No. 47.	No. 49.	No. 51.	No. 48.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total solids	13.07	10.35	16.20	14.52	6.92	15.37
Sucrose	9.00	6.50	13.50	10.65	3.55	11.40
Purity	68.85	62.99	83.33	74.73	51.14	74.16

From the above analyses it is seen that we have in these beets one remarkable sample, No. 38, which shows the highest content of sugar in the juice of any beet heretofore analyzed in the United States. In addition to this there are other excellent samples, namely: No. 35, No. 39, and 47, all of which would yield large quantities of sugar when properly manufactured. The other samples as indicated by the analyses are practically worthless for sugar-making purposes.

From John Jenkins, Lincoln, Nebr., two samples of sugar beets, which, on being analyzed, gave the following results:

No. 31, grown by B. Thompson, Swanton, Nebr.; variety, Lane's Imperial; planted last of May; harvested October 1; soil, black loam.

No. 53, grown by Wellfleet Land and Improvement Company, Wellfleet, Nebr.; variety, Vilmorin; planted June 1; harvested November 9; soil, sandy loam.

Analytical data.

	In the juice.	
	No. 31.	No. 53.
	Per cent.	*Per cent.*
Total solids	14.65	20.27
Sucrose	10.40	17.05
Purity	70.98	84.11

No. 53, as indicated by the above analyses, is a beet of very superior quality, and if a crop of the same kind could be grown and manufactured by the best methods, it would yield not less than 250 pounds of sugar per ton of beets.

No. 31 is of rather inferior quality and would not yield over 130 or 140 pounds of sugar per ton.

From the annotations accompanying the analyses it is easy to discriminate between the good and bad varieties which have been received. The general result of the work leaves little doubt of the fact that there are many parts of the United States peculiarly suitable to the production of a sugar beet containing a large percentage of saccharine matter.

CULTIVATION OF SUGAR BEETS.

For the benefit of many interested parties I will give here a short description of the method of raising sugar beets, together with the method of manufacture of sugar therefrom, and will refer those who are more particularly interested in the matter to a bulletin which is now in course of preparation and will be issued shortly by the Department devoted to the production of sugar from the sugar beet. Copies of this bulletin when published can be had by addressing a request to that effect to the Secretary of Agriculture.

Many varieties of beets are grown for the production of sugar, but these are all nearly related botanically, and the variations are based largely upon slight differences in the shape or color of the plant. The botanical name of the sugar beet is the *Beta cicla* or the *Beta vulgaris*, and different varieties which are now under cultivation have been developed from the original form by careful culture and selection. The different varieties of beets, as named in commerce, as has already been indicated, are determined by differences in size, color, and peculiarities of the leaves as well as in the differences in the size and color of the roots themselves. Some beets have their leaves standing upright, while others have them spread out over the soil; some leaves are smooth and others wrinkled; some are bright and others dark-green while the stems of the leaves are also of different colors. The roots are spindle-shaped, growing more or less towards spherical. The growing beet remains either entirely in the earth or is raised to a greater or less extent above the surface of the soil. The best beets for sugar-making purposes should have the following characteristics :

(1) The beet should be regularly spindle-formed to pear-shaped, with a simple and gradually tapering point and with as few as possible adhering rootlets to the sides.

(2) It should have a mean weight of from 1 to 1½ pounds. Smaller beets give too small a harvest and larger have generally a juice poorer in sugar.

(3) The interior of the beet should be white, hard, and firm. The beet should be a variety which grows as little as possible above the surface of the soil and should have a large number of leaves.

In Germany the chief varieties grown are the White Silesian, which is the most widely distributed and the highest priced; it is somewhat pear-shaped with broad leaves standing straight and with bright green stems. It has many subvarieties, among which the one with small crumpled leaves is the most highly prized.

The Quedlinburger is more slender, that is, more spindle-shaped,

with rose-colored head and reddish leaf-stems. It is better adapted for the heavy and richly manured soils, where the beets are grown closely together, while the Silesian is better adapted for poorer and sandier soils where the beets are grown wider apart.

The Imperial beet is slender, somewhat pear-shaped, with a white fine interior; the head small and growing entirely beneath the soil, with leaves bright green and upright and strongly wrinkled.

In France the beet known as the Vilmorin is the one which is most largely cultivated.

SOIL.

Any good soil is suitable for the growth of the sugar beet, but a sandy loam is perhaps best adapted for that purpose. The soil should be deeply plowed and thoroughly pulverized so as to allow the downward growth of the beet. Evidently a soil which is pulverized only to the depth of a few inches will not allow the tapering root of the beet to sink to a sufficient depth, and the result will be that the head of the beet will grow above the soil, thus exposing it to the dangers both of hot suns and early frosts.

CLIMATE.

For the production of the best class of sugar beets a cool summer is necessary. The effect of the hot suns of a warm summer climate is to soften the head of the beet even when it is carefully covered by the soil, thus rendering the storage of sugar in this part of the beet impossible. In the harvesting of such beets a large part of the top of the beet must be cut off in order to secure the remainder of a proper saccharine strength. Beets, however, grow very well on high plateaus, even in the southern climates, as in the neighborhood of Granada, Spain. During the past season beets were very successfully grown at Medicine Lodge, Kans., but the season was an exceptionally favorable one for the growth of beets, there being an absence of the hot winds which are so apt to prevail in that region during the months of July and August. The beets which were grown in that locality during the past season do not compare favorably with those grown in France and Germany, although the yield of sugar was satisfactory considering all the adverse circumstances.

As pointed out in Bulletin No. 5 of this division, the coast valleys of California are peculiarly suitable to the growth of the sugar beet, and later experiments have shown that many parts of Nebraska and Dakota also produce sugar beets of satisfactory saccharine strength. It is probable that the sugar beet area of this country will be found along the Pacific coast, on the high plateaus of Utah and Colorado, in certain parts of Nebraska and Dakota, in Southern Iowa, Minnesota, and Wisconsin, and in Northern Indiana, Ohio, and New York. Several years of experimenting will determine in what particular part of these localities the best soil and climate for the production of the sugar beet are to be found.

CULTIVATION.

The cultivation of the sugar beet is a matter of especial importance. The farmer who expects to grow a beet rich in sugar by simply planting the seed and plowing it a few times will be doomed to disappointment. The cultivation of the beet belongs rather to horticulture than to agriculture. It requires the frequent use of the hoe, careful

attention, and a close supervision, which it is not usual to give to field crops in this country.

The number of beets grown on a given area will depend largely upon the nature of the soil and the character of the fertilizer employed. In all cases the beets should be grown sufficiently close together to prevent any of them reaching a maximum weight of more than 2 pounds and to produce an average weight of about 1½ pounds. The number of beets per square yard to produce this result will vary from seven to fourteen. The beets should always be planted very thick and then thinned out when young to the proper distance to secure the number of beets above mentioned, according to the richness of the soil and the other conditions above noted. Aside from the hoeing and attention above mentioned, the cultivation of the beet is carried on much the same as any other field crop; the ground being kept pulverized and free from weeds until well covered by the leaves of the growing plants. The soil should also be thrown toward the beets in sufficient quantities to prevent them from protruding above ground.

HARVESTING.

The time for harvesting the beets usually begins about the 1st of October. They are to be thrown out of the soil by an appropriate plow, or beet digger built much upon the principle of an ordinary potato digger. The beets are then to be taken one by one and the leaves and a portion of the top taken off, which varies in extent with the position which the beet occupied in the soil. If the beet be grown well under ground only a small portion will be taken off with the leaves; if, however, it should protrude much above the soil a considerable quantity must be cut off. The tops of the beets contain very little sugar and a large proportion of the total salts of the whole plant, and it is important to secure a large yield of sugar by removing the proper amount of the top of the beet with the leaves.

After the beets have thus been harvested and topped, they are delivered either directly to the factory or else placed in heaps and covered with earth to protect them from freezing.

MANUFACTURE OF SUGAR BEETS.

It will be only necessary here to briefly indicate the nature of the process employed in the manufacture of sugar from the sugar beet; the details of the process, together with illustrations of the machinery employed will be found in the Bulletin already mentioned.

The beets delivered to the factory are first washed to remove all adhering dirt; they are then weighed and carried by an elevator to the slicing machine: this cuts the beets into appropriate pieces for the action of the diffusion liquids; the sliced beets are then carried by appropriate machinery to the diffusion battery, which resembles in every respect the battery used for the extraction of sugar from sorghum and sugar cane. After the extraction of the sugar the pulp is dropped on to appropriate carriers, then it is taken to the press, which removes from the pulp a large quantity of the water. The pressed pulp is then ready for cattle food, for which purpose it has considerable value.

The extracted juice is carried into large tanks, where it is treated with about 2.5 per cent. of lime; the lime is afterward precipitated by blowing through the liquid a stream of carbonic acid derived from

a lime-kiln attached to the factory. When the lime has all been precipitated the material is passed through a filter press, which separates completely the purified juice from all solid matters contained therein. In order to obtain a very pure juice this process of separation is repeated, sometimes twice. The pure juice thus obtained is evaporated to the consistency of a sirup in a vacuum multiple-effect apparatus. This sirup is then put into a vacuum strike-pan where it is crystallized and reduced to the proper degree of dryness. The mixed sugar and molasses from the strike-pan are carried to the centrifugal machine, where the molasses is separated and the sugar obtained in a dry state. The sugar thus obtained is what is known as raw sugar and is not yet fit for domestic use. If pure sugar is desired, bone-black filters are attached to the factory by means of which the juice is rendered pure and the sugar white.

The total cost of a complete apparatus for manufacturing sugar from sugar beets on a commercial scale will vary from $75,000 to $250,000, according to the size of the factory and the character of the buildings and machinery employed.

A sugar beet containing 12 per cent. of sugar will yield about 200 pounds of sugar per ton. A large quantity of sugar remains still in the molasses, and this is separated in various ways, either by the process of osmosis, by means of which the soluble potash and other salts in the molasses are removed, or by treating the molasses with strontia or lime and subsequently separating the sucrates of strontia and lime thus produced.

EXPERIMENTS IN THE PRODUCTION OF BEET-SUGAR AT MEDICINE LODGE, KANS.

The Medicine Lodge Sugar Company conducted an interesting sugar experiment in the production of beet-sugar, of which the following data are presented:

Number of acres planted	4.7
Tons of clean beets produced	60.23
Pounds of sugar made	10,158
Gallons of molasses made	380

Of the total sugar mentioned above, 2,800 pounds were second sugars. The cultivation received by the beets was as follows:

They were planted rather thick, and after they had come up they were thinned out to the proper distance The laborers had instructions to throw the dirt up around the beets after they were well grown. This part, however, of the instructions was neglected, and the consequence was that a portion of the beets grew above ground, and that part did not contain any saccharine matter, and had to be cut off with the tops, thereby causing a large waste. The beets were worked without many of the appliances usually found at a beet-sugar factory. They were washed by means of a hose, and cut by the cane shredder. The skimmings and settlings were run into the waste ditch, instead of being utilized. The beets were grown upon five different pieces of ground, within a radius of 2 miles of the sugar works, and all upon what is called second bottom soil. None of the plots was irrigated. The seeds were obtained in Germany by Mr. Hinze, and from 7 to 8 pounds were used in planting one acre of ground. The beets were planted the 1st of May, but should have been planted at least two weeks earlier.

The analytical data obtained in the experiments in the manufacture of beet-sugar are as follows:

	Date.	Brix corrected to 17.5° C.	Sucrose.	Purity.
			Per cent.	
Exhausted chips	Nov. 14	1.60	.62	38.75
Do	15	2.24	.82	32.14
Means		1.92	.72	35.14
Fresh chips	14	13.74	9.00	65.50
Do	15	12.09	9.67	71.71
Means		12.91	9.33	68.60
Diffusion juice	14	10.83	7.89	72.76
Do	15	10.99	7.37	67.16
Means		10.91	7.63	69.96
Clarified juice	14	11.64	7.77	66.58
Do	15	10.65	6.35	59.62
Means		11.14	7.06	63.20
Semi-sirup	14	25.26	18.10	71.61
Do	15	29.32	18.80	64.61
Means		27.29	18.45	68.11
Massecuite	16	85.68	49.31	56.39
Molasses	24	77.71	32.11	42.00
Raw sugar			90.90	
No. 16 reboiled sugar			90.90	

PRODUCTION OF SORGHUM SUGAR.

The Department of Agriculture during the past year has carried on extensive experiments in the production of sugar from sorghum. These experiments may be divided into two great classes: First, culture experiments, having for their object the production of new varieties of cane and the improvement of old varieties in sugar content; second, manufacturing experiments, including aid in furnishing new machinery to factories and in exercising a complete chemical control of manufacture.

The culture experiments were carried on at the following stations:

At College Station, Md., two plots were cultivated in different varieties of cane, one by Mr. D. M. Nesbit and the other by Maj. H. E. Alvord, the director of the Maryland Agricultural Experiment Station.

Mr. Nesbit's plot contained 5 acres, and the station plot 10 acres. These plots were laid off regularly into small parcels, and a great many different varieties of cane were planted thereon. The fertilizers employed had the following composition:

Description of samples.

No. 1..........Fine bone.
No. 2..........Corn guano.
No. 3..........Muriated potash.
No. 4..........Kainite
No. 5..........Ammonite.
No. 6..........Acid phosphate.
No. 7..........Ammoniated dissolved bone.
No. 8..........Ammonium sulphate.
No. 9..........Dried blood.
No. 10..........Thomas slag.
No. 11..........Nitrate of soda.
No. 12..........Dissolved bone-black.
No. 13..........Sulphate of potash.
No. 14..........Cotton-seed hull ash.

Analyses.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Moisture	7.44	15.78	.62	9.58	8.26	11.78	10.67
Total phosphoric acid	29.68	14.53	....	....	4.62	20.30	18.69
Soluble phosphoric acid	....	....	....	....	....	11.44	6.73
Reverted phosphoric acid	....	....	....	....	....	7.00	8.09
K_2O	....	....	49.97	12.37	....	....	....
Ammonia	4.59	2.24	....	....	15.12	.44	....
	No. 8.	**No. 9.**	**No. 10.**	**No. 11.**	**No. 12.**	**No. 13.**	**No. 14.**
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Moisture	....	....	.22	....	18.31	12.72	5.96
Total phosphoric acid	....	....	19.59	....	16.42	....	8.67
Soluble phosphoric acid	....	....	....	....	15.34	....	....
Reverted phosphoric acid	....	....	....	....	.74	....	....
K_2O	....	....	....	....	....	27.20	25.45
Ammonia	24.45	14.90	....	18.05	.82	....	....

The method of applying the fertilizers and the quantity per acre will be fully described in Bulletin No. 26, which is now in course of preparation and will be issued shortly.

On account of the extremely wet spring, planting was not commenced on the plots until late in May and not completed until late in June. The excessive rains continued during the entire season, making it almost impossible to cultivate the plants, many of which were entirely drowned out. The results were extremely unfavorable, the canes produced being poor in sugar, although in some instances the tonnage per acre was quite satisfactory. The general results of the experiments tend to show that sorghum as a sugar-producing plant is a complete failure in a wet season such as was experienced here in 1889.

The culture experiments at Sterling were conducted on a plot of about 35 acres, on which many different varieties of cane were grown. The season at Sterling was much more favorable and the results were quite encouraging. It was proved beyond doubt by the process of selection, commenced at Sterling by the Department last year, it was possible to distinctly improve the sugar-producing qualities of sorghum. Cane grown from seed selected last year on account of a high sugar content showed a distinct improvement in its sugar-producing properties, leading to the expectation of an early and permanent improvement in the varieties from an economic point of view. In general it may be stated that the production of new varieties is not so much desired as the improvement by selection, proper cultivation, and fertilization of the varieties already known.

In regard to the fertilization it is unfortunate that the wet season spoiled the experimental attempts at the Maryland Station for determining the effect of different fertilizers and mixed fertilizers upon the sugar-producing quality of the plant. It is to be hoped that this experiment may be continued in coming years in order that this point may be definitely determined.

At the Sterling Station no fertilizers were employed, the natural fertilization of the soil alone being relied upon to produce the crop. It must not, however, be expected that sorghum, as a sugar-producing plant, will have a history different from other plants grown for that purpose. No matter how fertile the original soil may be the

time will soon come in the course of cultivation when artificial fertilizers must be resorted to in order to produce a paying crop. It is far better to get a few acres of heavy canes rich in sugar than many acres of light canes poor in sugar. When it is considered that if we can produce a sugar-producing plant which will yield from 150 to 250 pounds of sugar per ton and a yield of 10 to 15 tons of plants per acre, only a few millions of acres of land will be necessary to produce the entire sugar supply of the country, the importance of seed selection and fertilization from an economic point of view is at once rendered prominent. In view of all the data which has been collected by the Department it is proper to say that future experiment of a public nature in the production of sugar from sorghum lies almost wholly within the lines of work above indicated. It has already been demonstrated that certain kinds of machinery are most effective in the production of sorghum sugar, and the locality has been pretty definitely pointed out in which the plant grows most favorably. It remains, therefore, for the Department to pursue its investigations in the improvement of the cane, in order that the farmer may have placed in his possession the proper varieties of seed for the production of a plant having the maximum content of available sugar. If, in addition to this, certain experiments are conducted looking to the more perfect separation of the sugar from the molasses, the Department will have done all for the grower and sorghum sugar manufacturer that can be reasonably demanded. The full details of the culture experiments at Sterling will be found in the forthcoming Bulletin No. 26.

MANUFACTURING EXPERIMENTS.

This class of experiments has been conducted by the Department at the following points:

Cedar Falls, Iowa; Rio Grande, N. J.; Morrisville, Va.; Kenner, La.; Medicine Lodge, Attica, Conway Springs, Liberal, Arkalon, Meade, Minneola, and Ness City, Kans. In addition to the above places the machinery belonging to the Department at Fort Scott, Kans., has been used by the Parkinson Sugar Company at that place, although the Department has furnished no financial aid or chemical control for the work there.

The full details of all the above experiments will be given in Bulletin No. 26.

The general results of the manufacturing work have been disappointing in their nature. So far as the economical production of sugar is concerned, it may be said that the experiments at Cedar Falls, Rio Grande, Morrisville, Kenner, Liberal, Meade, Arkalon, Minneola, and Ness City were decided failures. At Fort Scott, Conway Springs, and Attica an amount of sugar was made which may be roughly given at 350,000 pounds for each place. At Medicine Lodge a decidedly larger amount of sugar was made, which, from present advices, will reach nearly 500,000 pounds. Returns from these stations of an economic nature have not yet been received, so it is impossible to state whether or not these factories have been run at a profit. From information already at hand, it would seem that one of them at least, viz, Medicine Lodge, has produced sugar, if not at a profit, certainly nearly so. It must not be forgotten, however, that in all these localities in Kansas a State bounty of 2 cents per pound is given, which it is not expected, nor probably desired, should remain permanently in force. It can not, therefore, be said with

truthfulness that the sugar industry is economically successful until it is rendered independent of this *pro tempore* aid.

It may be of interest to give here a few of the general results obtained in each of the localities where manufacturing experiments were carried on.

CEDAR FALLS.

From the reports made in 1888 by the Iowa Agricultural Experiment Station it was thought by many of the farmers of that State that sorghum sugar could be produced at a profit. This theory was strongly contradicted by the facts previously set forth in the publications of the Department, which show that in a latitude as far north as Iowa it is hopeless to expect the establishment of a successful sorghum sugar industry. Although it is true that certain early varieties of sorghum cane may be grown and matured in the State, yet it is likewise true that early frosts and the early advent of winter prevent a manufacturing season of sufficient length to justify the expectation of success in the manufacture of sugar from a plant so capricious as sorghum. Nevertheless, in order to satisfy the demands of the Iowa farmers, $5,000 was set aside for conducting experiments in the manufacture of sugar, and this money was spent under the direction of the Bozarth Bros., of Cedar Falls, who have for many years successfully carried on a sorghum sirup factory at that place. The proper machinery for manufacturing sugar was added to the factory and the attempt made to manufacture sugar, but, as was expected by the Department, without success. Very little sugar was made, and the early close of the season, due to a short crop, prevented the continuation of experiments in this direction. The claim which has been persistently made in some quarters, that sorghum can be successfully grown in any locality where maize will produce a crop, is certainly not warranted by the facts and is calculated to mislead capital and to excite hopes among agriculturists which can not be realized. I deem it, therefore, my duty to speak plainly on this subject and to warn both farmers and capitalists in regard to the dangers of investing in sorghum sugar factories in high northern latitudes.

RIO GRANDE.

The experiments in the manufacture of sugar at Rio Grande are of chief value on account of the light which they throw upon the gradual deterioration of the cane at that place. It is a remarkable fact that although the experience of years has served to guide both farmer and manufacturer, nevertheless the results of the year's work are less hopeful of future success than any of the previous years. With the exception of a very small plot containing 2.9 acres, the cane at Rio Grande was totally unfit for sugar-making. This was probably largely due to the wet and cloudy season, although it but confirms the results obtained in the last few years at that place. The cause of this deterioration of the sorghum is not well understood. It can hardly be due to admixture with broom-corn, since no such admixture is known to have taken place. It may be due to the fact that the sorghum at Rio Grande has developed a tendency to the production of large quantities of seed to the deterioration of the cane, as ascribed to this cause by Mr. Horton, my assistant at Rio Grande. It is more probably due to insufficient heat and light. The history of the plot from which the sugar was made is as follows:

The field has been in sorghum cane during the seasons of 1882, 1883, 1884, 1885, and 1886, and the present season. In 1887 and 1888 clover was grown on this plot and the clover plowed under. The planting of the plot was finished on the 15th of May. Some replanting was required, which was finished on June 7. The fertilizer employed was "specific guano" at the rate of 150 pounds per acre, which was put in the hill. The cane was twice cultivated and the weeds were pulled out thoroughly in August. The cane received no hoeing. The average percentage of sucrose in the juice from the 2.9 acres was 11.14. The amount of sugar made was 2,900 pounds, or 1,000 pounds to the acre. The sugar was of a low grade, polarizing about 84.

In general it may be said that in 1889, on account of the wet spring, the attempt was made at Rio Grande to make up for late planting by the use of forcing fertilizers. This favorable result shows what may be accomplished when the same conditions can obtain over the whole plantation as were found in the small plot. It is quite remarkable, however, that other parts of the same field, which in all respects had been treated as the plot which produced the sugar, failed to develop as rich a cane and consequently the amount of sugar produced from the other parts of the field was insignificant in quantity. On the whole it must be confessed that the production of only about 3,000 pounds of sugar in the whole season's work and from 200 acres of cane is not at all encouraging.

MORRISVILLE.

The history of the experiments at Morrisville is only a repetition of the difficulties, so far as field work is concerned, that were encountered in Maryland and New Jersey. The season was one of continuous rains and the planting and cultivation of the crop was necessarily conducted in the mud. At Morrisville the rains, after a portion of the planting had been accomplished, were so heavy that over acres of ground the seeds were utterly washed out and the seeding had to be done again. The varieties planted were Early Orange, Link's Hybrid, Late Orange, White African, Early Amber, and Improved Orange. The planting commenced about the middle of May and was not completed until the end of June. By reason of this late planting by the beginning of September the best plots of cane, although healthy in appearance, were undergrown and uneven. The late planted plots, certain of which were more even, could only become developed to a sugar-making value under the influence of a long and mild autumn.

The machinery was hastily constructed and imperfectly put together, and even had the cane been suitable for sugar-making purposes it could not have been profitably worked. The numerous analyses disclosed an average of sucrose in the juice of the cane from the 151 acres examined of only 7.3 per cent. The averages of sucrose of the different varieties were as follows:

	Per cent.
Early Amber	5.5
White African	9.3
Early Orange	7.4
Late Orange	8.4
Improved Orange	7.9
Link's Hybrid	10.1

Of the Link's Hybrid, which proved to be the best variety of cane, only 4½ acres were grown, while of the Early Amber, which proved to be the poorest, 53 acres were cultivated. The crops of sorghum grown by farmers near the factory gave much better results than the crop grown by the company itself. The average of ten different plots grown outside of the company's land showed an average content of sucrose of 9.9 per cent. in the juice of the cane; this indicated a crop which might yield from 60 to 70 pounds of sugar per ton.

Although the season's results were unfavorable, the fact that in some instances farmers produced crops containing a considerable percentage of sucrose would indicate that in Virginia sorghum might, under a careful cultivation and study of its habits, become a paying plant for sugar-making purposes. Unless, however, the average of the crop can be considerably improved there is no early expectation of the realization of this hope.

KENNER.

The experiments in the manufacture of sugar at Kenner were conducted on a smaller scale than those which have previously been noted. They were made at the sugar experiment station of Louisiana by Dr. W. C. Stubbs, the director of that station. Examinations of the canes were made beginning on July 30 and continuing until August 25, and a study of the percentages of sucrose therein made during those intervals. Studies were also made of different varieties of cane grown on the State Experiment Station at Baton Rouge, in some of which large percentages of sucrose were found. Other varieties were also grown on the North Louisiana Experiment Station, at Calhoun, with a uniformly large percentage of sucrose in the juice and a high co-efficient of purity.

Sugar-house results.—The diffusion battery employed at Kenner consisted of fourteen cells, each with a capacity of 13½ cubic feet. The clarification of the juice was practiced by adding lime to the cell, and this clarification was performed with varying success, depending entirely upon the heat obtained. When clarification was not completed in the cells it was finished in the clarifiers. From the clarifiers the juice was conducted to a double-effect vacuum pan and evaporated to a sirup; the sirup was sent then to the vacuum strike-pan, where the concentration was completed. The manufacture of sugar from sorghum commenced on the 4th of September in a trial with Early Amber. This sorghum was badly injured by the cane-borer. The entire interior of the stalk was red, and both the mill and diffusion juices were intensely red, which color could only be discharged by filtration through bone-black. No sugar was made from this first run, but only sirup. On September 5 another trial run was made on the Early Amber from the same plot. The analysis of the juice showed 8.3 per cent. sucrose and 4.71 per cent. of glucose. Only sirup was made from this run. On September 9 another run was made with Early Orange grown from seed raised at the station. This cane was cut on the 4th of September, at which time it showed 7.1 per cent. sucrose and 4.70 per cent. glucose; it was left in the yard in the open air until the 9th of September when the analysis showed 5.6 per cent. sucrose and 5.6 per cent. glucose. This was therefore deemed unfit for sugar making and was only boiled to sirup.

On September 10, Early Orange, Kansas Orange, and New Orange

were diffused; the juice was colored slightly red. An attempt was made to make sugar from this, but without success. It was therefore boiled to string proof; placed in the hot room, where it remained for three weeks; it was then passed through the centrifugal, where it yielded 62 pounds of brown sugar per ton of cane. The average percentage of sucrose in the juice from which this sugar was made was 9.7, and of glucose 2.85 per cent. The sugar made polarized 82.3 per cent. On September 13 experiments were made with Link's Hybrid, and the yield was 85 pounds of sugar to the ton, polarizing 94.7 per cent. The mean composition of the juice from which this sugar was made was 10.1 per cent. of sucrose and 2.12 per cent. of glucose. On September 22, further experiments were made with different varieties of cane, but all having low percentages of sucrose, so that no sugar was made from them. On September 24 sorghum was shipped from Baton Rouge to Kenner. Several of the best varieties were selected for this shipment; the cane was of excellent quality, fine size, and in the right stage of maturity; it was harvested and shipped on one day and worked up on the next; the juice was clear, diffusing easily, and boiling well. It would not, however, granulate in the strike-pan without assistance, and accordingly a small amount of crystallized sugar was added to the sirup. The sirup made was dried with difficulty, yielding 119.8 pounds per ton. The average composition of the juice from which this sugar was made was 11.3 per cent. sucrose and 2.42 per cent. glucose. The cane grown in Madison Parish and shipped to the station was worked on September 22 and gave 98 pounds of sugar to the ton. The average composition of the juice from this sample was 9.25 per cent. sucrose and 3.57 per cent. glucose. In regard to the general character of the work Professor Stubbs makes the following comments:

The sorghum grown at Kenner was of an inferior character; that grown at each of the other stations and at Mr. Maxwell's very fine.

The soils of each of these places vary greatly. At Kenner the soil is a black, heavy, tenacious clay, hard to cultivate and harder still to drain, susceptible of injury from either extreme of drought or excessive rain-fall. Small seed, if not too deeply planted, germinate quickly in it. At Baton Rouge the brown loam of the bluff formation prevails: a soil which withstands drought well, but can not endure excessive rain-fall. Small seed are with difficulty germinated; due to the soil puddling and forming an impervious crust after every shower. It works with ease, but it is difficult to drain. At Calhoun there exist the sandy and loamy tertiary soils, easily worked and drained; a soil whose physical properties are good, and which needs only proper fertilization to make excellent crops in propitious seasons. At Mr. Maxwell's we have the typical alluvial soil of the Upper Mississippi bottoms; a sandy soil easily worked and drained and of great fertility. These four soils well represent all the soils of the State, save the red lands of Red River bottoms and the light prairie fields of southwestern Louisiana.

The seasons at each of these places varied greatly during the period of the growth of sorghum. At Kenner a prolonged drought, following a heavy rain-fall of April 13, greatly injured the sorghum, making it small and spindling. When the rains began on last of June it produced suckers, greatly to the detriment of the cane. The cane-borer also attacked the sorghum at Kenner and did it considerable damage.

The same drought prevailed at Baton Rouge, but the seed implanted in April did not germinate until June, and hence the young plants were not stunted as at Kenner. No worms or suckers interfered.

At Calhoun most propitious seasons prevailed and the canes were fair in quantity and quality.

At Mr. Maxwell's fine seasons prevailed in the early growth of the cane, but near maturity a prolonged drouth was encountered, which doubtless injured the cane.

In reviewing the agricultural results, it may safely be asserted that dry, well-drained, loamy soils are best adapted for sorghum and that showers at regular intervals favor a large sugar content as well as tonnage. Neither drouths nor excessive rain-falls are favorable to a full development of this plant.

Another feature worthy of note: Only certain varieties of sorghum have given good results anywhere. Link's Hybrid, originated by Mr. Ephraim Link, of Greenville, Tenn., seems to have succeeded better on a large scale than any other variety. Of the one hundred varieties tested this year for the first time only a very few are worthy of further trial.

The sugar-house results were disappointing. In every instance difficulty was experienced in graining in the pan. Only by the addition of crystallized sugar or by the withdrawal for some time of heat could graining be started. Even at a temperature of 120° Fahr., with a vacuum of 26 to 28 inches, no grain could be formed. Does our sorghum contain more dextrine and soluble starches than that raised in Kansas? Or did we diffuse at too high a temperature? Our records show temperatures ranging from 40° to 80° C. in our discharging tanks, and yet no preceptible difference in the sirups. Samples of all the molasses have been kept to further study their compositions.

Our greatest difficulty was in purging our massecuite; a great surprise to all. After running the centrifugal some time it was found on examination that a layer of sugar adhered to the sieve, upon which rested a layer of molasses, and this in turn was covered by a layer of white foam giving the appearance, while the centrifugal was in motion, of a beautiful white sugar. After stopping the centrifugal these layers had to be broken down and mixed with a little water and again centrifugalled. In this way a good sugar was obtained, but only at the expense of time, patience, and considerable loss of sugar.

CONWAY SPRINGS.

The factory at Conway Springs was transferred during the early part of the year from the original Conway Springs Sugar Company to the Kansas Sugar Company, which operated the plant during the season just past. The new company undertook to improve the plant and contracted with the Kilby Manufacturing Company, of Cleveland, for $30,000 worth of new machinery. In addition to the battery used the first year a second battery was constructed, so that the factory was operated with two small batteries instead of one large one, thus increasing the expense and complication of the work. The new machinery was not tested until the 25th of August, and the usual delay in the starting of the machinery was experienced. Warned by the experience of last year, the company undertook to procure pure water for the diffusion battery and for use in the boilers, through a 4-inch pipe line laid to a creek one mile away. Unfortunately the machinery which raised the water from the well had not been put in proper condition and considerable loss of time was caused by its failure to do the work at the commencement of the season. In addition to this the water supply was deficient, the water which came in through the pipe line not being in sufficient quantities to meet the purposes of the house.

Several weeks were lost on account of this insufficient supply, the work in the meantime lagging, so it was necessary to run first one part of the house and then wait until the other had caught up. Finally a pond was constructed near the mill and the waste water used over again for condensing purposes. As a result of all these imperfections the season's work was one continuous interruption. All these delays were caused by defects patent from the beginning, and which past experience should have induced the company to provide against. The greater portion of the month of September was consumed in this way and only about 1,500 tons of cane were cut, enough only for one week's work of the factory properly conducted.

These troubles appear to have brought about a general demoralization, and during the month of October, although the work was somewhat more steady, there were many delays caused by breaking drags, elevators, and pumps and other accidents, the result of gross carelessness, and some perhaps unavoidable. The double effect

caused some delay by the tubes becoming coated with scale, necessitating the removal of the heads of the pans and the scraping of the tubes.

The exhausted chips were removed from the battery by means of carts and dumped on the adjacent prairie. Four two-horse carts, with drivers, and six additional men were employed for this work, a daily expense of about $19—a very much larger expense than would be necessary if proper arrangements were made for the disposal of the exhausted chips.

The chips furnished to the diffusion battery by the cutters in the early part of the season were very fine and in excellent condition for diffusion. Later the knives became badly broken from stones and pieces of iron which found their way to the shredders, and little attention was paid to setting and grinding the knives properly; hence, with a very large dilution only a moderate extraction was secured.

The new battery gave better results than the old. This was due partly to the shape of the cells of the new battery, narrowing toward the top with a small top door, but chiefly it was due to the larger juice pipes and better circulation thereby secured.

In general it may be said that the heavy machinery was entirely adequate and suitable for the work, and that the delay and trouble should not be charged to this, but rather to carelessness and inexperience, and the breakages and imperfections in the smaller parts of the machinery which ordinary care in the preparation of the machinery should have avoided.

The character of the cane worked.—The character of the cane worked for sugar at Conway Springs was rather above the average for sorghum. The average composition of the juice taken from samples of the fresh chips as they entered the batteries for the whole season was as follows:

	Per cent.
Sucrose	11.98
Glucose	1.70
Total solids	18.33

These figures show a juice well suited for sugar-making purposes, and which, worked as closely as possible with ordinary appliances, ought to yield fully 120 pounds of sugar to each ton of fresh chips.

As indicated by the analytical work in the early part of the season, but little inversion of sucrose was noticed in the battery. Later this inversion was greater, and it was decided and deemed advisable to add sufficient lime to the chips in the battery to correct this. The skimmings and settlings were returned to the battery. The clarification of the juice was aided by liming to neutrality or nearly so and heating to the boiling point in open clarifiers. Some inversion was noticed between the clarifying juice and semi-sirups. This was due chiefly to the manner in which the juice was handled, which for a long time was allowed to stand for the purpose of settling before evaporation. The purity of the sirups was fair, and these sirups were grained without difficulty in the vacuum strike-pan. The sugar was boiled to a very fine grain, and this fact, as well as the inexperience of the workmen and the little attention paid to keeping the hot room to the proper temperature, caused the work with the centrifugals to be slow. The sugar also was heavily washed and a great deal of the fine portion found its way through the screens of the centrifugal into the molasses. The molasses therefore was found to be very rich in sugar, corresponding to the small yield of fresh sugar.

The total number of battery cells filled was 5,723. The old battery cells contained an average of 1,262 pounds per cell and the new battery 1,473 pounds, giving a total of 3,944.8 tons of chips which were diffused. The scale book of the factory shows that 4,596 tons of topped cane passed over the scales; 100 tons of this were unworked, some of it having spoiled while on the rack and the remainder being left in the shed when work was stopped. The total number of tons of topped cane worked was 4,496. From this cane were obtained 1,360,510 gallons of juice containing 711,801 pounds of sugar. This gave 228,800 gallons of semi-sirup containing 647,511 pounds of sugar. Sixteen thousand gallons of juice were lost by souring and waste containing 8,371 pounds of sugar. The battery work was interrupted and the battery drawn off 59 times, causing the loss of sugar from at least 60 tons of cane or about 6,000 pounds. The total loss of sugar in manufacturing may be tabulated as follows:

Loss of sugar by inversion	lbs..	64,290
Loss of raw juice	do..	8,371
Loss of sugar by drawing off of battery	do..	6,000
Total loss from diffusion to sirup	do..	78,661
Total fresh sugar made (*circa*)	do..	230,000
Molasses made	galls..	68,035

Of this molasses 8,424 gallons were sold and the remainder reboiled for sugar. The sugar contained in the reboiled molasses, viz, 58,611 gallons, amounted to 300,845 pounds. The quantity of sugar which the reboiling should give under the usual computation would be 156,388 pounds. Up to the present time the quantity of sugar obtained per ton of cane by reboiling is about 30 pounds. If the same rate is secured in the remaining portion of the molasses the yield of sugar at the factory during the year will be 363,570 pounds, and of molasses 48,566 gallons. Based upon the tonnage of the cane worked the yield would be 81.5 pounds of sugar per ton, and 10.9 gallons of molasses per ton.

The amount of sugar left in the chips was very large considering the dilution, and was due entirely to the very large chips furnished by the macerators to the diffusion battery.

The average percentage of fiber in the cane, as given by the analysis of the chips, was 11.49, which indicated the presence of 88.51 per cent. of juice in the cane. In the 3,954.8 tons of chips the amount of juice was 3,499 tons. This juice contained an average of 11.98 per cent. of sucrose, or in all 838,440 pounds, which would therefore leave in the chips 126,639 pounds of sucrose, or about 32 pounds of sugar to the ton of chips.

If the cane had been properly shredded this additional 126,639 pounds of sucrose would have been largely secured in the diffusion juice.

The company contracted with the farmers for 1,800 acres of cane; of this 200 acres were to be Early Amber and the remainder Orange. The company furnished the seed, and the greater part of the cane was planted on plowed land. The cane was not planted until May, and a number of acres had to be replanted, as the first planting was blown out. The season was unusually wet, the growth of the cane very rank, and the stalks large, averaging 14 feet in height. The tonnage was heavier than last year, the Amber giving 11 tons and the Orange 13 tons per acre when topped. Several hundred acres were planted on very poor land and did not mature; the remainder was fairly even in character. Owing to the late date at which the cane

was planted and the wet season, it did not mature until late. The greater part of the Amber cane was worked before it had attained its maximum content of sucrose. The Orange cane was at its best, as was the case last year, about the middle of October, after a light frost sufficient to kill the leaves.

Last year the richness of the cane was attributed partly to the dryness of the season. The present season was one having the largest rain-fall known in Kansas, and yet the average percentage of sucrose was 11.98 and of glucose 1.78; the average for 1888 being 12.42 and 2.61 respectively. This agreement in the content of sucrose is important from an agricultural point of view when the opposite characters of the two seasons are considered. The seed from last year's crop had been carefully hand picked and threshed from the richest plots of last year, and from this source the Medicine Lodge and Attica factories obtained most of their seed.

In this connection it is important to note the results obtained from Amber cane. The seed was selected from a plot which last year showed a sucrose content of 14.09 per cent. and glucose 1.26 per cent. This year seed producing a cane showing 13.10 per cent. of sucrose was planted on unplowed land and 13.20 per cent. on plowed land. In all cases there was a decrease in total solids as compared with last year and there was a corresponding increase in the purity of the juice. It was also noticed, this season as well as last, that while the Amber cane deteriorated rapidly if left any length of time after being cut, the Orange cane after it had attained its maximum content of sucrose was fairly stable. Several hard freezings did not materially injure the cane, as can be seen by the analyses made during the latter part of the season.

The factory was forced to stop cutting on the 8th of November for reasons which will be mentioned further on.

About 600 acres of cane of excellent quality were left standing in the field. About November 4 there was a light fall of snow, but this did no damage to the cane. The total number of days actually worked, counting 22 hours per day, was 45; that is, the work should have been done in that length of time if the mill had been run continuously.

The expense for labor and coal was enormous and might have been greatly reduced with proper care.

In summing up the results of this season's work, it is but fair to mention that the expense for labor and coal could scarcely have been a cent more if the mill had run steadily and done four times the work.

The assets of the company were:

Machinery and plant of the Conway Springs Sugar Company, including water works, actual value	$18,949.00
New machinery furnished by Kilby	30,500.00
Lumber, labor, etc., to put plant into shape for season's work	18,949.00
Total cost of plant	69,449.00
Expense account, including interest	1,830.00
Expenses during season.	
4,596 tons of cane, at $1.50	6,894.00
Labor, including salaries	9,100.00
Coal and oil	3,500.00
Incidentals	869.00
Barrels	680.85
Total	21,043.85

Receipts.

230,000 pounds of sugar, at 6 cents	$13,800.00
67,035 gallons of molasses, at 10 cents	6,703.50
	20,503.50
State bounty, 2 cents per pound	4,600.00
	25,103.50
	21,043.85
Profit	4,059.65

Interest on investment of 5½ per cent.

The United States Government gave to this company $8,000 for the purchase of machinery; so that the actual amount of money for which the stockholders were liable was $63,279. Owing to the fact that these stockholders were not able to meet the obligations for their shares of stock when payments were due and lacked ready capital to run the business, it was necessary to stop work. When, however, the product is all sold, including the State bounty, a small percentage upon the investment will be shown.

This poor result should not be blamed upon the industry but upon the people who engaged in it without financial resources.

For this reason again we have gone into the particulars of the troubles in order to show that it is not the fault of the business but of the way in which it is run that no better results have been secured. We do not intend any personal reflection, but deem it but fair in justice to the industry to state what we have.

In 1888 we made the statement that a great success could be secured at Conway Springs, provided improvements were made in the machinery and the management was good.

Though good machinery was purchased from the Kilby Manufacturing Company it was not all advantageously placed, and there was lacking the necessary experience to make the work successful. When some man or men with money select a site in the section of the State of Kansas near Conway Springs, erect an improved and substantial plant where there is an abundant pure water supply, and run it on legitimate business principles, with the intention of being satisfied with a good interest on the investment, then the sorghum sugar business in Kansas will be profitable both for investor and farmer.

The results of the trial run made from October 27 to November 1 were: 639.6 tons of cane worked, giving 47,944 pounds of sugar and 9,640 gallons of molasses, or 74.9 pounds of sugar and 15 gallons of molasses per ton of cane. From the molasses by reboiling an additional 30 pounds of sugar per ton and 8 gallons molasses were obtained, making per ton of cane 104.9 pounds sugar and 8 gallons molasses.

Expenses

639.6 tons of cane at $1.50	$959.40
Four days labor	613.20
Coal	200.00
Incidentals	25.00
Barrels	30.00
Total	1,847.60

Receipts.

47,944 pounds of sugar at 6 cents	$2,876.64	
9.640 gallons of molasses at 10 cents	964.00	
		$3,840.64
Profit		1,993.04

This of course does not take into account interest on the investment, but shows that if a factory is run steadily money must be made.

The figures showing the respective percentages in the material and products of this run can be seen from the table:

Total number of tons of cane purchased	4,596
Total number of tons of cane worked	4,496
Number of tons of chips	3,954.8
Number pounds of sugar in chips	838,440
Number pounds of sugar obtained in diffusion juice	711,801
Number pounds left in chips and lost by inversion	126,639
Number pounds of sugar in semi-sirup	647,511
Number pounds of sugar in juice lost	8,371
Number pounds of sugar lost, attributable to inversion	64,290
Number pounds of sugar obtained firsts	230,000
Number pounds of sugar in molasses, less molasses sold	300,845
Available sugar in the molasses	156,388
Pounds of sugar in the molasses sold	43,226

ATTICA.

The character of the cane worked for sugar at Attica during the season can best be judged by the summary of the analyses taken in monthly periods during the course of manufacture. For August and September the mean composition of the juice of the cane sampled at the battery was as follows:

In the juice.

Sucrose	per cent..	9.95
Glucose	do....	2.29
Total solids	do....	15.96
Juice in the cane	do....	88.70
Cane received	tons..	2,197.2
Total sugar in the cane	pounds..	321,942.00
Total glocuse in the cane	do....	75,850.00
Total available sugar	do....	208,167.00
Sugar per ton of cane	do....	176.20

The data for the month of October are as follows:

In the juice.

Sucrose	per cent..	12.69
Glucose	do....	1.51
Total solids	do....	17.72
Juice in cane	do....	88.70
Cane received	tons..	1,914.00
Total sugar in the cane	pounds..	426,552.00
Sugar per ton of cane	do....	231.10
Total glucose in cane	do....	43,972.00

For November:

In the juice.

Sucrose	per cent..	12.13
Glucose	do....	1.36
Total solids	do....	17.41
Juice in cane	do....	88.30
Cane received	tons..	591.6
Total sugar in cane	pounds..	127,347.00
Glucose in cane	do....	13,804.00
Sugar available	do....	106,643.00
Total sugar per ton of cane	do....	214.10

Summary for the whole season.

Clean cane received	tons..	4,702.8
Field cane received	do ...	7,184.00
Loss in cleaning cane	per cent..	34.53
Average per cent. of juice in cane	do....	88.60
Total sugar in cane	pounds..	875,841.00
Total glucose in cane	do....	133,626.00
Sugar per ton of cane	do....	186.20

In regard to the working of the battery and the degree of extraction obtained, the following data may be cited:

For August and September:

Mean sucrose in exhausted chips	per cent..	.63
Dilution	do....	30.30
Extraction	do....	89.80
Loss of sugar per ton	pounds..	17.20

For October:

Mean sucrose in exhausted chips	per cent..	1.59
Dilution	do....	34.00
Extraction	do....	85.70
Loss of sugar per ton	pounds..	31.50

For November:

Mean sucrose in exhausted chips	per cent..	1.46
Dilution	do....	30.10
Extraction	do....	86.40
Loss of sugar per ton	pounds..	29.10

For the season:

Mean sucrose in exhausted chips	per cent..	1.22
Mean dilution	do....	31.50
Mean extraction	do....	87.30
Mean loss of sugar per ton	pounds..	25.90

In regard to the inversion which took place during the process of manufacture the following data may be cited:

For August and September:

Total inversion	pounds..	9,096.00
Inversion per ton of cane	do....	8.10
Sucrose in fresh chips inverted	per cent..	2.80

For October:

Total sugar inverted	pounds..	3,626.00
Inversion per ton of cane	do....	2.10
Sucrose in fresh chips inverted	per cent..	.85

For November:

Total inversion of sugar	pounds..	1,619.00
Inversion per ton of chips	do....	2.80
Sucrose in fresh chips inverted	per cent..	1.27

Means for the season:

Total inversion of sugar	pounds..	14,341.00
Sucrose in fresh chips inverted	per cent..	1.64

From the records of the company as received on the 16th of December, the total cost of fuel, exclusive of the seed burned for fuel and the fuel used in working second sugars, was $2,791.32; total cost of labor, exclusive of construction and labor used in boiling seconds, $9,987.58; the total product of first sugar, 262,038 pounds.

Estimating the yield of seconds at 30 pounds per ton, which is, considering the richness of the molasses, a moderate estimate, the quantity of second sugars obtained at this factory would be 141,060

pounds. Adding this to the product of first sugars, viz. 262,038 pounds, the total yield of sugar would be 403,098 pounds. The yield per ton of clean cane on this estimate would be 85.3 pounds, and the yield per ton of field cane, including the seed heads, would be 56.4 pounds.

The usual difficulties and delays in manufacturing sorghum sugar were experienced by this company, including, at the beginning, scarcity of water and other minor delays due to deficient working of different parts of the machinery. The average number of tons of field cane worked per day was only 97, whereas before the opening of the season it was supposed that the factory had a capacity of 250 tons per day. This failure of the factory to work up to its capacity was one of the chief causes of the financial troubles into which the company fell. On account of these financial troubles, on the 19th of October the Kansas State Sugar Company, at Attica, passed into the hands of a receiver.

When the richness of the cane worked is considered we must justly charge the failure of the company to secure a profit on their work to the mechanical difficulties encountered in the manufacture and the losses experienced due to deficient machinery and the inexperience of the workmen. In no other way can we satisfactorily explain the small yield of sugar per ton on cane of such uniform richness and good quality as was grown at Attica during the past season. At the time of closing the factory, the 12th of November, a large quantity of cane still remained in the field and of good quality for sugar-making purposes. This cane was of course lost, and the stoppage of the factory was due solely to the financial difficulties of carrying the work further, although the cane was commencing to deteriorate. With anything like a fair working of the house, the whole of the crop should have been worked up by the 1st of November, and the total amount of sugar made in this case would greatly have exceeded the amount obtained.

It is but fair to say that had the cane crop at Attica been worked promptly, with the proper machinery and at the proper rate per day and with the economy which ought to have been secured, the quantity of sugar made would have probably reached 600,000 pounds and the season's work shown profit instead of a deficit.

Full details of this work will be found in Bulletin No. 26, already noted.

MEDICINE LODGE.

The results of the manufacture of sugar from sorghum at Medicine Lodge were in every respect the most satisfactory of those obtained anywhere else during the season. The latest advices, December 11, which we have from this place show that about 500,000 pounds of sugar will be made, including firsts, seconds, and the beet sugar. In all, the factory was operated about fifty days and the whole of the sugar which was made will have been made in this time barring the usual delays incident to the use of new machinery.

The results of the season's work in general detail will be found in the following data:

The mean composition of the juice entering the diffusion battery, as obtained from samples of the fresh chips during the entire season, was—

	Per cent.
Sucrose	10.44
Glucose	2.24
Total solids	16.40

The analytical data disclose a juice of very even composition during the entire season, the maximum percentage of sucrose being 13.45 and the minimum 8.27; the maximum percentage of glucose 4.52 and the minimum 1.03.

The mean composition of the diffusion juice for the entire season is as follows:

	Per cent.
Sucrose	7.13
Glucose	1.45
Total solids	11.40

The mean composition of the juice from the exhausted chips during the entire season is as follows:

	Per cent.
Sucrose	1.20
Total solids	2.09

This shows rather a poor extraction, since with good shredding of the cane and good battery work the percentage of sucrose left in the juice of the chips ought not to be above 0.40 per cent.

The mean extraction on the percentage of sugar in the cane for the season was 90.2 per cent., and the mean dilution of the juice 30.58 per cent. The sucrose lost in the chips amounted to 20.4 pounds per ton of the clean chips.

From the above data much encouragement will be derived for the sorghum-sugar industry. One of the chief things accomplished by the Medicine Lodge Company was the abundant water supply which they secured. It was the only one of the factories operated under the Department auspices in Kansas which had a sufficient supply of water. In another season, with the experience obtained during the past one, it is confidently believed that with such a location as that at Medicine Lodge, and with a crop equally good, a handsome profit can be obtained both for the farmers and the manufacturers in the production of sugar from sorghum. This, however, should not induce every one to believe that a hap-hazard investment in sorghum sugar factories, without proper study of the conditions of the problem, the character, and abundance of the water supply, the nature of the soil and climate, and the necessity of expert supervision, would produce a profitable return. Success can only be hoped for in such an industry when advantage is taken of all favorable conditions, when the machinery is erected by skilled engineers and is fully adequate to the purpose required, and when all the operations of manufacture are conducted with the greatest economy and on the strictest business principles.

OPERATIONS AT NESS CITY, MEADE, ARKALON, LIBERAL, AND MINNEOLA.

The factories above mentioned were located in the arid region of Kansas and, as it appears to me, without sufficient consideration of all the difficulties to be encountered. It is certainly true that experience has shown that sorghum is well suited to a dry climate, but there is no assurance that it will grow successfully as a sugar-producing plant in the arid regions. It is true that future experiment may develop the possibility of growing sorghum in the localities mentioned above and with a sufficient content of sugar for practical purposes of manufacture. It however betrayed a strong degree of

rashness to establish large and expensive sugar factories before having thoroughly tested the agricultural capabilities of the several locations where these factories were placed.

Sorghum has been grown in the arid region of Kansas for many years as a forage plant, but no attempts have ever been made to grow it for sugar-making purposes. The agricultural results at all the places mentioned above were most disastrous. The cane was planted without consideration of the needs of the plant, on ground insufficiently plowed and sometimes not plowed at all, and without taking any precautions to guard against the drought which is certain to prevail during the hot summer months.

On October 2 it was reported by our agent from Meade that the country was badly dried up and the cane crop ruined. At Liberal the cutting of cane was stopped on the 1st of October, after a twelve days run in which 700 tons of cane were manufactured. A small quantity of sugar was made at this place but of course nothing in a commercial way. It was also reported that there was a prospect of trouble between the farmers and the sugar company. The sugar company made a binding contract with the farmers to take all their merchantable cane and pay them $1.50 per ton; it was claimed by the farmers that the cane was ready to work into sugar by the 20th of August and that had the works been ready at that time a large percentage of the cane could have been worked into sugar and would have been merchantable. On the 2d of October the sugar company was still working at Arkalon trying to get a supply of water.

This failure to locate a sugar factory where a sufficient supply of water can be had seems somewhat strange after the publications of the Department last year in regard to this subject. In fact there seems to have been no consideration allowed to the most important factors of the problem of sugar making in the locations of these several factories. At that date, viz, October 2, no work in the manufacture of sugar had been undertaken at Arkalon and the season passed without any sugar having been made.

At Meade an attempt was made to manufacture sugar during the last week in September, and on the 2d of October they attempted to make a trial run of twenty-four hours in order to manufacture 150 tons of cane, since the company agree in accepting the bonds voted by the people at that place to erect machinery which had a capacity of this amount. After, however, making a run of some hours the factory had to shut down on account of failure in the water supply, thus failing to make the run of the 150 tons in the time specified.

The results of the work at Liberal is indicated by what has been said above, the failure of the cane crop, the failure to have the factory ready in time, and the failure to have a sufficient amount of water had it been ready, being the lamentable history. The Department made an effort through its publications to warn people of the difficulties attending the manufacture of sorghum sugar, and yet they seem to have paid little attention to these warnings, but listened rather to the representations of others, and were thus led to the voting of bonds for the erection of factories in impossible places and having no hope of success.

What is necessary in localities like Meade, Liberal, and Arkalon is first a thorough study of the agricultural problems. It is possible that by deep plowing or subsoiling sufficient moisture may be secured to carry a sorghum crop through the dry season and to mature

it for sugar-making purposes. Certainly, however, the methods of agriculture practiced during the past season, of planting on imperfectly plowed soil or in soil not plowed at all, or without any precaution to secure the deep rooting of the plants, can only end in failure unless an exceptionally wet season could be secured.

At Minneola the Adamson roasting process was tried, and on October 6, when our last report from there was received, they had been running the apparatus about eight days, working 275 tons of cane. At that time no attempt had been made to make sugar. Later reports indicate that some fraud was practiced in the sugar made later in the season by means of which the people were deceived in regard to the true capacity of the plant and the character and amount of sugar made. The theory of the roasting process is first to pass the canes through a long furnace, in which the leaves and sheathes thereof are burned off, leaving the canes cleaned and softened by the heat. The canes are then passed through an ordinary mill and the juice used for the manufacture of sugar in the ordinary way. Whether or not this principle can be made successful in practice can only be determined by further trial. In case it should be successful there is no reason why it should not be used preliminary to diffusion, thus saving the fanning and cleaning machinery now employed for that purpose with sorghum. As was the case in the other places, the factory could work very little of the time on account of a failure in the water supply.

At Ness City the story of failure which is told of the above places is to be repeated. The factory at Ness City was run in a desultory way for about ten days and several strikes of massecuite were made, but not a single pound of sugar was secured. The cane was in even worse condition than at Minneola, Meade, Arkalon, and Liberal. The factory was closed up at first and one of the townships that had voted bonds refused to pay them. The factory was then started up again and an attempt made to run long enough to legally obtain the bonds. As in the case of the other factories, the water supply was very limited and the factory could only run a part of the time on this account.

The unwise attempts to establish sugar factories and make sugar at the localities mentioned above are to be deplored, not only on account of the hardships which they impose upon the people, already poor, who voted public credit to the aid of these factories, but especially on account of the depressing influence they will have on the progress of the sorghum-sugar industry already struggling under a burden of disasters difficult to bear. When it is considered that from the very first the attempts which have been made to manufacture sugar from sorghum have been financially unsuccessful, the persistency with which the people have tried to establish this industry and the patience with which they have borne the disasters are alike remarkable. They show a strong belief which pervades a great part of our agricultural community of the necessity of the establishment of an indigenous sugar industry, and the sacrifices they are willing to make in order to secure this most desired result. The record of the above disasters does not prove that the sorghum-sugar industry is impossible, but emphasizes the fact that the conservative and unbiased conclusions of the Department of Agriculture are a far safer guide for the intending investor than the representations of irresponsible and interested parties.

PRODUCTION OF SUGAR FROM SUGAR CANE.

Although the Department did not have direct charge of any work in the production of sugar from the sugar cane in Louisiana during the past year, nevertheless three of the chemists of the Department were detailed to go to Louisiana and exercise chemical control in three of the leading factories of the State. The results of these investigations were published in Bulletins 21, 22, and 23.

Bulletin No. 21 deals particularly with the report of the experiments in the application of diffusion to the manufacture of sugar at Magnolia. The results of the work thoroughly demonstrate the practical manufacturing value of the process as applied to sugar cane. In the third run of the sugar-house, from December 1 to 8, inclusive, in which diffusion alone was worked, 1,079 tons of cane were manufactured, yielding 213.23 pounds of sugar per ton. In the fourth run, from December 9 to 22, inclusive, 1,799 tons of cane were manufactured, yielding 240.11 pounds of sugar per ton. In the fifth run, from December 23 to January 14, inclusive, 3,062 tons of cane were worked, yielding 214.45 pounds of sugar per ton. The results of the work show an immense increase in the amount of sugar yielded by this process over that obtained by the old process of milling. It is evident, from a careful comparison of the figures obtained by the average mill work, that the yield of sugar per ton of cane throughout the whole State would be increased fully 75 pounds over the present yield by the general adoption of the diffusion process. It is true that that amount of increase would not be secured over the best milling but only the average milling as practiced in Louisiana.

In Bulletin No. 22 are given the results of the factory of Shattuck & Hoffman, at Des Lignes plantation, which was operated solely by the crushing process. As a result of the work done at this station, as compared with the diffusion work, the proprietors of that factory were led to reject the mill entirely and to build and operate during the past season a diffusion battery.

Bulletin No. 23 contains the results of the season's work at Mr. Daniel Thompson's Calumet plantation, in which double crushing was practiced with saturation of the bagasse between the mills with hot water. The results obtained in this way were the highest yet noted in Louisiana with milling.

The average quantity of total sugars obtained per ton of cane was 206.85 pounds.

FOOD ADULTERATION.

Part 5 of Bulletin 13, devoted to food and food adulterants, has been published since the last Annual Report. This part treats of baking powders. The character and scope of the work are illustrated generally in the prefatory note, in which the following statements are made:

> The present part consists of an investigation of baking-powders and a résumé of our present knowledge of the subject.
>
> In these investigations we have used every endeavor to avoid error and bias. No particular powder has been favored at the expense of any other one. Our samples have been purchased in the open market, and we have had them to represent as fairly as possible the character of the goods sold.
>
> In such an investigation it is not possible to get results which will please every dealer and manufacturer, and we may therefore expect that many of our data will

be distorted or denied by interested parties. A more serious embarrassment may also confront us, and that is the use of isolated portions of this report for advertising purposes.

The public official who lends the name and authority of his office for advertising purposes has little regard for either and less for the proprieties of his position. He has, however, no longer control of the data of his analyses when they have once been published by the proper authority.

It would be well, in view of such facts, if the use of such matter for advertising purposes could be absolutely forbidden. In the present case I would like to emphasize the statement that any data or statements in the present bulletin which may be paraded by advertisers in praise of their wares would show a discrimination wholly unauthorized by the spirit and scope of this work.

In spite of the precautions mentioned in this note the work has been made a basis of many advertisements, in which it is made to appear that the Department indorses and especially commends certain brands of baking-powders in comparison with others. At the present time a scientific man can only fully and fairly express his views and state the results of his scientific investigations at the risk of seeing his name paraded in print as an indorser of almost every kind of commodity which is placed upon the market. The chemist engaged in private work and occupying no public position is at perfect liberty to allow the use of his name for such purposes, but the official chemist occupies an entirely different position. It is not so much the name of the chemist as the influence of the office which he holds which the advertiser desires to use, and the frequent occurrence of his name in advertisements and circulars does much to discredit his work among scientific men.

CHARACTER AND CONSTITUTION OF BAKING POWDERS.

By C. A. Crampton.

AERATION OF BREAD.

When bread is made by simply mixing flour with water and baking the dough, the result is a hard, tough, compact mass, "the unleavened bread" of the Scriptures. The use of yeast to "leaven" the dough is doubtless almost as old as the art of baking itself. Both kinds of bread are mentioned in Mosaic history, and its use was known in Egypt and in Greece at very early periods. Nothing has ever been found that could equal the action of yeast as a leavening agent. Carbonic-acid gas is generated by fermentation from the carbohydrates already existing in the bread, so that no foreign materials are introduced into it. The disengagement of the gas takes place slowly, so that it has its full effect in the lightening of the dough. This is an objection to its use, of course, when quick raising is desirable, and it is this slow action of yeast which has been the chief cause of the introduction of a chemical aerating agent.

The method of aeration invented by Dr. Dauglish, in England, in March, 1859, approximates more closely the action of yeast than any other method in so far as it introduces no permanent foreign substance into the bread. In his method water which has been previously charged with carbonic dioxide is used in making up the dough, the operation being performed in a closed vessel, under pressure. As soon as the dough is taken from this vessel it immediately rises, from the expansion of the gas contained in it. The method has been modified by using instead of water a weak wort, made

by mashing malt and flour, and allowing fermentation to set in. This acid liquid absorbs the gas more readily, and perhaps has some slight effect on the albuminoids, the peptonization of which constitutes an advantage of yeast-raised bread over that made by this method, in which the aeration is purely a mechanical operation. Thus the bread made by this process is somewhat tasteless, the flavors produced by fermentation within the bread being wanting. On the other hand, there is no danger of the improper fermentations which sometimes occur, and the process is especially adapted to flours which would be apt to undergo such changes when fermented. Jago* says with reference to it:

> Working with flours that are weak or damp or even bordering on the verge of unsoundness, it is still possible to produce a loaf that should be wholesome and palatable, certainly superior to many sodden and sour loaves one sees made from low quality flours fermented in the ordinary manner. In thus stating that it is possible to treat flours of inferior quality by this aerating method, the author wishes specially to carefully avoid giving the impression that it is the habit of those companies which work Dauglish's method to make use of only the lower qualities of flour; he has never had any reason whatever for supposing such to be the case.

This method is in operation in all the larger cities of Great Britain, but I have no knowledge of its being used in this country.

CHEMICAL AERATING AGENTS.

The necessity of sometimes having bread preparations raised quickly for immediate baking led to the use of chemical agents for this purpose. In all of these the expansive gas is the same as where yeast is used, but instead of its being derived from the constituents of the flour it is obtained by the decomposition of a carbonate which is introduced, together with an acid constituent to act upon it, directly into the flour. When water is added to make the dough the chemicals are dissolved, the reaction occurs, and the carbonic acid is set free, while the salt resulting from the combination of the acid with the alkaline base of the carbonate remains in the bread and is eaten with it. Many suppose, and this idea is fostered by baking-powder manufacturers, that nothing remains in the bread, that everything is driven off during the baking. This is entirely erroneous, of course, and the residue necessarily left in the bread by baking-chemicals constitutes an objection to their use, and its amount and character determine to a large extent the healthfulness of the combination used. The essential elements of such a combination are, first, a carbonate or bicarbonate which contains the gas combined with an alkaline base; and, second, an acid constituent capable of uniting with the base in the carbonate and thus liberating the carbonic acid gas. For the alkaline constituent bicarbonate of soda, "baking soda," is almost exclusively employed—bicarbonate of ammonia much less. For the acid constituent, however, there is great diversity in the agents used. When the housewife mixes sour milk with baking-soda to "raise" her griddle-cakes, she makes use of the free lactic acid of the former as the acid constituent of her chemical aerating agent. When she uses "cream of tartar" or acid tartrate of potassium with soda, she uses the free tartaric acid of the former as an acid constituent, and this is the same combination that is used in one class of the baking-powders sold in the market. In fact, the entire line of such powders now sold is practically the outcome of

*Chemistry of Wheat, Flour, and Bread, and Technology of Bread-making. London. 1886.

the old-time operation of domestic chemistry, mixing "saleratus" and "cream of tartar" to aerate rolls, muffins, pancakes, and such bread preparations, which were to be baked immediately after mixing, and could not well wait for the slow operation of yeast. They consist of an acid and an alkaline constituent in about the proper proportions for combination, and in a dry state, together with various proportions of a dry, inert material, such as starch, added to prevent action between the chemicals themselves, so that the preparation may be kept indefinitely.

CONSUMPTION OF BAKING-POWDERS.

The quantity of the different chemical preparations made and consumed under the name of "baking-powders," "yeast-powders," etc., in the United States can not be stated with any degree of accuracy; neither the Statistical Division of this Department nor the Bureau of Statistics of the Treasury was able to give any information whatever upon this subject. Mr. F. N. Barrett, editor of the "American Grocer," advised me that the New York Tartar Company would probably be best able to give something of an idea, at least, of the amount produced. A letter of inquiry sent to this firm elicited the following response:

DEAR SIR: Your note of inquiry of the 22d instant was received in due course of mail. We have delayed reply thereto because of the difficulty of securing with any degree of reliability the information you seek. We believe that no one can give a correct estimate of the quantity of baking-powder annually consumed in the United States, but we are led to conclude from rather careful consideration that it amounts to between 50,000,000 and 75,000,000 pounds. Of this quantity probably two-thirds is made from cream of tartar, and the residue from phosphate and alum.

Very respectfully,

NEW YORK TARTAR COMPANY.

This would seem rather a high estimate, implying as it does an annual average consumption of a pound each by every man, woman, and child in the country. Probably few persons would suppose that it reached such a figure. Taking the price per pound at 50 cents, which is about the maximum retail price charged the consumer, together with the lower of the two figures given above, we would have $25,000,000 as the amount annually paid by consumers for this one article.

Granting that the above is somewhat of an overestimate, there can be little doubt that no other article which enters into the composition of food-stuffs, and which is not of itself a nutrient, is the subject of so great an expenditure.

The consumption of baking-powders does not seem to have become so extensive in Europe as in the United States, judging from the very small amount of attention bestowed upon the subject in works on food. Jago* makes but slight mention of their use. Doubtless the American people eat more largely of preparations of breadstuffs which are baked quickly, such as rolls, buns, etc.

In view of the large quantity of these preparations now consumed, and a lack of knowledge amongst most people concerning their composition and the chemical reactions that occur in their use, I have thought it proper to give a somewhat detailed exposition of the principles involved, and to endeavor to explain, even to the non-scientific reader, how these powders are made, and how they act.

* Op. cit.

RECENT INVESTIGATIONS.

Two important studies of the composition and character of baking-powders have been made recently, one under the direction of the Ohio Dairy and Food Commission, and the other by the Dairy Commissioner of the State of New Jersey*. Work done in this way, which has the authority and weight of official sanction, is most valuable, and I have drawn largely upon the reports above mentioned in the following pages. Many other analyses of baking powders have been made from time to time, and several extensive investigations have been carried out upon the relative merits of different kinds of powders. In fact "baking-powder literature" is quite extensive. The active competition between makers of different brands, and the methods used by them in advertising their goods, have made readers of newspapers and magazines familiar with all sorts of parti-colored statements about baking-powders in general and certain classes and brands in particular, and unfortunately such matter is not always confined to advertising columns. Most persons know comparatively little about baking-powders, and the general ignorance on the subject is taken advantage of and intensified by the manufacturers. The analyses and testimonials of eminent chemists frequently appear in such advertisements, and are often couched in terms that do little credit to the profession. I can make no use of such publications; the only material I can accept as trustworthy are the reports cited above, where the official character of the work done affords ample assurance that the investigators were influenced by unbiased and disinterested motives. It is the proper province of such bodies as State boards of health to make investigations of this kind, and results arrived at in this way are always entitled to credence, while the conclusions of scientific men, however expert they may be, are always open to doubt when they receive compensation from parties who are interested in having the results lean in their direction.

ADULTERATION.

There is no recognized standard for the composition of a baking-powder, either in this country or abroad. To prove from a legal point of view that a powder was adulterated, it would be necessary to show that it contained some substance injurious to health. Most of the treatises on food adulteration give but little attention to this class of substances, which, though not of themselves articles of food, enter into the composition of food preparations. Considerable space is devoted in such works, however, to the adulteration of bakers' chemicals. If a substance is sold as cream of tartar, for instance, which either is not cream of tartar or is sophisticated with some cheaper substance, the seller could be convicted under food-adulteration laws, but if such a fraudulent cream of tartar were incorporated into a mixture with other chemicals and the whole sold as baking-

* While the present publication was passing through the press, I have received another official publication upon this subject, constituting Bulletin No. 10 of the Laboratory of the Inland Revenue Department, Ottawa, Canada, and prepared by A. McGill, assistant to chief analyst. I regret that it appeared too late to allow of the incorporation into the present publication of any of the results and conclusions contained in it. Most of the powders examined were of Canadian manufacture, but the leading American brands were also included, and the analyses were quite complete.

powder, no conviction could be secured. In the famous "Norfolk baking-powder case" in England, which will be alluded to further on, the powder in question contained alum, which substance bakers are not allowed by law to use in bread. Yet the prosecution was not successful because it was directed against the sale of the powder, not against the bread made from it, there being no legal standard for substances sold as baking-powder in England.

CLASSIFICATION OF BAKING-POWDERS.

Baking-powders may be conveniently classified according to the nature of the acid constituent they contain. Three principal kinds may be recognized as follows:

(1) Tartrate powders, in which the acid constituent is tartaric acid in some form.

(2) Phosphate powders, in which the acid constituent is phosphoric acid.

(3) Alum powders, in which the acid constituent is furnished by the sulphuric acid contained in some form of alum salt.

All powders sold at present will come under some one of these heads, although there are many powders which are mixtures of at least two different classes.

TARTRATE POWDERS.

The form in which tartaric acid is usually furnished in this class is bitartrate of potassium or "cream of tartar." Sometimes free tartaric acid is used, but not often. Bitartrate, or acid tartrate of potassium, is made from crude argol obtained from grape juice. It contains one atom of replaceable hydrogen, which gives it the acidity that acts upon the carbonate. The reaction takes place according to the following equation:

$$\underset{\substack{\text{Potassium}\\\text{bitartrate.}}}{\overset{188}{KHC_4H_4O_6}} + \underset{\substack{\text{Sodium}\\\text{bicarbonate.}}}{\overset{84}{NaHCO_3}} = \underset{\substack{\text{Potassium-sodium}\\\text{tartrate.}}}{\overset{210}{KNaC_4H_4O_6}} + \underset{\substack{\text{Carbonic}\\\text{dioxide.}}}{\overset{44}{CO_2}} + \underset{\text{Water.}}{\overset{18}{H_2O}}$$

It will be seen that the products of the reaction are carbonic acid and double tartrate of potassium and sodium, the latter constituting the residue which remains in the bread. This salt is generally known as Rochelle salt, and is one of the component parts of seidlitz powders. A seidlitz power contains 120 grains of this salt, but the crystallized salt contains four molecules of water, and thus the actual amount of crystallized Rochelle salt formed in the baking-powder reaction is greater than the combined weight of the two salts used; that is to say, if 184 grains of bitartrate and 84 grains of bicarbonate are used in a baking there will be a residue in the dough equal to 282 grains of Rochelle salt. The directions that accompany these powders generally give two teaspoonfuls as the proper amount to use to the quart of flour; probably more is generally used. This would be at least 200 grains; deducting 20 per cent. for the starch filling we have 160 grains of the mixed bitartrate and bicarbonate, and this would form 165 grains of crystallized Rochelle salt in the loaf of bread made from the quart of flour, or 45 grains more than is contained in a seidlitz powder. The popular idea is that the chemicals used in a baking-powder mostly disappear in baking, and that the residue left is very slight. I doubt if many persons understand that when they use tar-

trate powders, which are considered to be the best class, or at least one of the best classes of such powders, they introduce into the breadstuff very nearly an equal weight of the active ingredient of seidlitz powders, and in a loaf of bread made from it they consume more than the equivalent of one such powder.

Yet the character of this residue is probably the least objectionable of any of those left by baking-powder. Rochelle salt is one of the mildest of the alkaline salts. The dose as a purgative is from ½ to 1 ounce. "Given in small and repeated doses it does not purge, but is absorbed and renders the urine alkaline." (United States Dispensatory.)

Free tartaric acid, used instead of the bitartrate of potassium, would give less residue. In this case the reaction would be as follows:

$$\underset{\text{Tartaric acid.}}{\overset{150}{H_2C_4H_4O_6}} + \underset{\text{Bicarbonate of sodium.}}{\overset{168}{2NaHCO_3}} = \underset{\text{Tartrate of sodium.}}{\overset{230}{Na_2C_4H_4O_6.2H_2O}} + \underset{\text{Carbonic dioxide.}}{\overset{88}{2CO_2}}$$

Here 150 grains of tartaric acid, with 168 grains of bicarbonate of sodium, give 230 grains of residue, or 88 grains less than the combined weight of the two ingredients. As to the character of this residue little is said in regard to the physiological properties of tartrate of sodium in the books, but probably it is essentially similar to the double tartrate. The United States Dispensatory says of it (p. 1762):

> This salt, in crystals, has been recommended by M. Delioux as an agreeable purgative, almost without taste, and acting with power equal to that of the sulphate of magnesium in the dose of 10 drachms [600 grains].

I do not know why this combination should be used so seldom by baking-powder manufacturers. The free tartaric acid is more expensive than the bitartrate, but less of it is required in proportion to the amount of bicarbonate used. The former is more soluble, and this would probably be a practical objection to its use, as it is an object in baking-powders that the gas should be liberated slowly. It would perhaps be more difficult also to prevent action of the free acid upon the alkali, so that the powder would be more likely to deteriorate in keeping. Only one sample among those I examined was found to have been made with the free acid.

One obstacle formerly encountered in the manufacture of bitartrate powders was the difficulty of obtaining the bitartrate pure. It contained from 5 to 15 per cent. of tartrate of lime incident to the method of manufacture. This brought a large quantity of inert material into the powder and lowered its efficiency. Bitartrate can now be had 98 per cent. pure, quoted and guarantied as such in the markets, so that there is no excuse for manufacturers to use the impure salt, which can properly be considered adulterated.

PHOSPHATE POWDERS.

The salt commonly used to furnish the phosphoric acid in this class is acid phosphate of lime, sometimes called superphosphate. The pure salt is monocalcic phosphate, $CaH_4(PO_4)_2$. It is made by the action of sulphuric acid upon ground bone, the result being an impure monocalcic phosphate with calcium sulphate. This mixture is sold as a fertilizer, as superphosphate. The salt is, of course, more or less purified for use in baking-powders, but the sulphate of lime is very difficult to get rid of entirely, and most phosphate

powders contain considerable amounts of this impurity. The reaction which occurs when a phosphate powder is dissolved, that is the action of bicarbonate of soda upon monocalcic phosphate, is not well established, and perhaps varies somewhat with conditions. The following equation probably represents it fairly well:

$$\underset{\substack{\text{Monocalcic}\\ \text{phosphate.}}}{\overset{234}{CaH_4(PO_4)_2}} + \underset{\substack{\text{Bicarbonate of}\\ \text{soda.}}}{\overset{168}{2NaHCO_3}} = \underset{\substack{\text{Monohydrogen}\\ \text{calcic phosphate.}}}{\overset{136}{CaHPO_4}} + \underset{\substack{\text{Disodic}\\ \text{phosphate.}}}{\overset{142}{Na_2HPO_4}} + \underset{\substack{\text{Carbonic}\\ \text{dioxide.}}}{\overset{88}{2CO_2}} + \underset{\text{Water.}}{\overset{36}{2H_2O}}$$

Two hundred and thirty-four grains of monocalcic phosphate combined with 168 grains of bicarbonate of soda give 136 grains of monohydrogen calcic phosphate, and 142 grains of disodic phosphate. But crystallized sodic phosphate contains twelve molecules of water, and has a molecular weight of 358. So the total amount of residue from 402 grains of the powder would be 494 grains, of which 136 grains is phosphate of lime and the rest phosphate of soda. So we see that here also the quantity of chemicals introduced into the dough is fully equal to the amount of the baking-powder used, including filling. As to the nature of this residue in phosphate powders, it would seem to be about as unobjectionable as in the tartrates. Phosphate of soda is "mildly purgative in doses of from 1 to 2 ounces" (480–960 grains) according to the United States Dispensatory. Phosphates of calcium have the general physiological effect which is ascribed to all forms of phosphoric acid, but which does not seem to be well understood.

Phosphates are administered therapeutically in some cases of defective nutrition, and especially in scrofula, rickets, phthisis, etc. On account of their being an essential constituent of animal tissues there would seem to be some ground for a preference over other forms of powders. The makers of phosphate powders claim that the use of such powders restores the phosphoric acid present in the whole grain of wheat, which is largely removed in the bran by milling processes. This claim would have more weight if there were not ample sources of phosphoric acid in other forms of food, and if the quantity introduced by a baking-powder were not much greater than is required to make up the loss in the bran, and greater than is required by the system, unless in those cases where its therapeutic use is indicated, as in some of the conditions of malnutrition given above.

Acid phosphate of soda is said to have been used in former years as a constituent of baking-powders, but appears to have been entirely superseded by the lime salt.

ALUM POWDERS.

In this class the carbonic acid is set free from the bicarbonate by the substitution of sulphuric acid, which combines with the sodium. The sulphuric acid is furnished by some one of the general class of salts known as alums, which are composed of a double sulphate of aluminium and an alkali metal. The alum is precipitated as hydrate, while that portion of the sulphuric acid which was combined with it goes to displace the carbonic acid in the bicarbonate. The alkali sulphate of the double salt remains unchanged.

The alum of commerce is either *potash alum*, $K_2Al_2(SO_4)_4.24H_2O$, or *ammonia alum* $(NH_4)_2Al_2(SO_4)_4.24H_2O$, the one or the other predominating according to the relative cheapness of the alkali salt it

contains. At the present time nothing but ammonia alum is met with, but at previous periods potash alum was the salt sold exclusively as "alum." Both salts are alike in general appearance and can not be distinguished apart by cursory examination.

Potash alum may be made directly from some minerals, such as the "alum stone" mined in Italy, which contain all the constituents combined. Ammonia alum, however, as well as most potash alum, is made by the combination of the constituents obtained from different sources. The sulphate of alumina is obtained by the action of sulphuric acid upon pure clays, and the sulphate of ammonia from the residue of gas-works. Solutions of the two salts in proper proportions are mixed and the double salt obtained by evaporation and crystallization.

Crystallized potash or ammonia alum contains twenty-four molecules of water, nearly one-half of its weight. Part of this water is lost at as low a heat as 60° C., and it is driven off entirely, though slowly, at 100° C. "Burnt alum" is simply alum deprived of its water of crystallization, which is generally driven off at about 200° C. Ammonia alum decomposes at 205° C.; potash alum at a somewhat higher temperature. Burnt alum is somewhat hygroscopic, but dissolves more slowly in water than the crystallized salt.

I have been unable to ascertain in what condition the alum is used for compounding baking-powders. Burnt alum would seem to be the form best adapted for this purpose on account of its slow solubility. Professor Cornwall says this is the form* used, but does not state how he obtained the information; and he states further that "crystallized alums may be used in connection with burnt alum to secure at first a more rapid escape of carbonic-acid gas." It is probable that the amount of drying given the alum used differs with different manufacturers, but it is not likely that the water of crystallization is entirely driven off.

The following equation shows the reaction taking place in a baking-powder made with burnt ammonia alum:

$$\underset{\substack{\text{Sulphate of aluminium}\\ \text{and ammonia, or}\\ \text{"burnt alum."}}}{\overset{475}{(NH_4)_2Al_2(SO_4)_4}} + \underset{\substack{\text{Bicarbonate of}\\ \text{soda.}}}{\overset{504}{6NaHCO_3}} = \underset{\substack{\text{Hydrate of alumin-}\\ \text{ium.}}}{\overset{157}{Al_2(OH)_6}} +$$

$$\underset{\substack{\text{Sulphate of}\\ \text{soda.}}}{\overset{426}{3Na_2SO_4}} + \underset{\substack{\text{Sulphate of am-}\\ \text{monia.}}}{\overset{132}{(NH_4)_2SO_4}} + \underset{\text{Carbonic dioxide.}}{\overset{264}{6CO_2}}$$

If potash alum were used the reaction would be precisely the same with the substitution of potassium for ammonia wherever it occurs in the equation, sulphate of potash being formed instead of sulphate of ammonia.

A study of the equation will show that 475 grains of burnt alum with 504 grains of bicarbonate will produce 264 grains of carbonic acid and leave a residue consisting of 426 grains of sulphate of soda, 132 grains of sulphate of ammonia, and 157 grains of hydrate of aluminium, the last named being a precipitate insoluble in water. Sulphate of soda crystallizes with ten molecules of water, so that the total weight of residue from the 979 grains of mixed chemicals would be 1,255 grains. If a hydrated alum is used in the powder,

* Report of the Dairy Commissioner of New Jersey, 1888, p. 70.

the proportion of residue to powder would of course be less, and the proportion of gas evolved would also be less. The character of the residue is seen to be more complex than is the case with any of the classes previously discussed, and deserves special attention. The sulphate of soda is similar to other alkali salts in its physiological action. Sulphate of ammonia is not used therapeutically, but probably has an action similar to that of other ammonia salts, such as the chloride. Professor Cornwall,* in his report, speaks as follows concerning this point:

> It is possible, however, that too little attention has been paid to the presence of ammonium salts in the residues from ammonia alum powders. * * * We do know, however, that ammonia salts, in general, are much more irritating and stimulating in their action than the corresponding soda salts, or even than the potash salts. For instance, Stillé and Maisch, speaking of ammonium bromide, state that it has a more acrid taste and is more irritating than potassium bromide. Its unpleasant taste and irritating qualities render it less convenient for administration than the bromide of potassium.
>
> We all know how mild a substance is chloride of sodium (common table salt); but of ammonium chloride Stillé and Maisch write: "The direct effects of doses of five to twenty grains of this salt, repeated at intervals of several hours, are a sense of oppression, warmth, and uneasiness in the stomach, some fullness in the head. If it is used for many days together in full doses, it disturbs the digestion, coats the tongue, and impairs the appetite." We have already seen how active a drug carbonate of ammonia is, and while, in the absence of proof, it would be rash to assert that sulphate of ammonia in five-grain doses is certainly injurious, yet there is abundant ground for further investigating its effect before asserting that it is milder in its effects than Rochelle salt. It may be that this question of the presence of ammonium salts in any considerable quantities in the residues of baking-powders deserves more attention than it has hitherto received.

It would seem from the above that there would be considerable difference between the physiological effects of potash and ammonia alums themselves. Yet the medical authorities make no such distinction. Ammonia alum is officinal in the British Pharmacopœia, and while the United States Pharmacopœia specifies potash alum, the particular form met with in trade is entirely determined by the comparative cheapness of manufacture.

The question of the relative harmfulness of these different salts in the residues of baking-powders is really one for the physiologist or hygienist to decide, not the chemist. Physiological experiments alone can decide them positively.

The consideration of the residue of hydrate of aluminium will be taken up later on.

POWDERS CONTAINING MORE THAN ONE ACID INGREDIENT.

As might be expected, some powders are met with which have been made up with various proportions of different acid ingredients, and which belong therefore to more than one of the above-mentioned classes. Professor Cornwall speaks as follows concerning some of these mixed powders:

> The makers of alum baking-powders sometimes add tartaric acid or bitartrate to their powders, either with or without the addition of acid phosphate of lime. This is doubtless done with the best intentions, either to secure a more rapid escape of carbonic-acid gas at the outset or otherwise improve the powder. We have found such additions in the case of several of our samples, but the presence of tartaric acid or tartrates in alum powders is very objectionable. If added in sufficient quantity to otherwise pure alum powders, they prevent the precipitation of the insoluble hydrate of aluminium entirely when the powder is boiled with water, and they may render much of the alumina soluble in water even after the bread is

*Op. cit., p. 77.

baked. Without doubt it would then be readily soluble in the digestive organs, producing there the effects due to alum or any other soluble aluminium compound. With one of our samples we found that the simple water solution seemed to contain as much alumina as a nitric-acid solution. In neither of these solutions could any of the alumina be thrown down by a slight excess of ammonia water, although it was readily precipitated from the solution first rendered alkaline with caustic soda, then slightly acidified with acetic acid and boiled with excess of phosphate of soda.

A case in which the character of the powder appears to be improved by such mixing, however, is furnished by the

ALUM AND PHOSPHATE POWDERS.

This combination seems to be a favorite one with manufacturers. In fact there are now comparatively few "straight" alum powders in the market, most of the cheaper grades being made of mixtures in various proportions of the alum with acid phosphate of lime. The reaction it is intended to obtain is probably the following:

$$\underset{\text{Ammonia alum.}}{\overset{475}{(NH_4)_2Al_2(SO_4)_4}} + \underset{\substack{\text{Acid phosphate}\\\text{of lime.}}}{\overset{234}{CaH_4(PO_4)_2}} + \underset{\substack{\text{Bicarbonate}\\\text{of soda.}}}{\overset{336}{4NaHCO_3}} = \underset{\substack{\text{Phosphate of}\\\text{aluminium.}}}{\overset{245}{Al_2(PO_4)_2}} +$$

$$\underset{\substack{\text{Sulphate}\\\text{of lime.}}}{\overset{136}{CaSO_4}} + \underset{\substack{\text{Sulphate of}\\\text{aluminium.}}}{\overset{132}{(NH_4)_2SO_4}} + \underset{\substack{\text{Sulphate of}\\\text{soda.}}}{\overset{284}{2Na_2SO_4}} + \underset{\substack{\text{Carbonic-}\\\text{dioxide.}}}{\overset{176}{4CO_2}} + \underset{\text{Water.}}{\overset{72}{4H_2O}}$$

If this equation be compared with the one representing the reaction in a powder made with alum alone, on page 170, it will be seen that in the former the alum goes into the residue as phosphate instead of hydrate, and the insoluble sulphate of lime takes the place of one molecule of sulphate of soda. Otherwise the reactions are similar. This reaction will only take place, of course, when the different ingredients are mixed in just the proper proportions to produce it. A number of variations may be produced by changing the relative proportions of the different ingredients.

THE "ALUM QUESTION."

The literature upon the subject of the use of alum in baking-powders, and upon the question as to its injurious effect upon the health of those who consume the bread made from it, is already quite extensive, and if quoted entire would fill a fair-sized volume. For the benefit of those who may desire to make an exhaustive study of it, I will make reference to all of the articles bearing upon the subject that have come under my observation, as follows:

Alum in baking-powder, by Prof. G. E. Patrick.—*Scientific American Supplement, No.* 185, 7, p. 2940.

Report of proceedings in the Norfolk baking-powder case (first trial).—*Analyst*, 4, p. 231.

Norfolk baking-powder case (second trial).—*Ibid.*, 5, p. 21.

Editorial comment on the case.—*Ibid.*, 5, pp. 13 and 34.

On the action of alum in bread making, by J. West Knights.—*Ibid.*, 5, p. 67.

Cereals and the products and accessories of flour and bread foods, by E. G. Love, Ph. D.—*Second Annual Report State Board of Health of New York*, 1882, p. 567.

On the solubility of alumina residues from baking-powders, by Lucius Pitkin.—*Journal American Chemical Society*, 9, p. 27.

Experiments upon alum baking-powders and the effects upon digestion of the residues left therefrom in bread, by Prof. J. W. Mallet.—*Chemical News*, 58, pp. 276 and 284.

As I have previously indicated, the matter of the physiological effect of the residues left by baking powders is not properly a chemical problem. On account of the interest and importance attached to it, however, it would seem necessary to give here somewhat of a résumé of the subject without attempting to arrive at a definite conclusion, or to settle, arbitrarily, the question as to whether the sale of certain forms of powders should be prohibited.

For a proper understanding of the alum question it is necessary to explain that the use of alum in bread-making is prohibited in countries having food-adulteration laws, such as England and France. This is partly on account of its injurious effect upon the system, but principally because of its peculiar action, not yet well understood, in improving the color and appearance of the bread to which it has been added, so that a flour of inferior grade, or even partially spoiled, may be used to make bread which will look as well, to all appearances, as bread made from much better grades.

Blyth* speaks as follows of this use of alum in bread:

> Alum is added to bad or slightly damaged flour by both the miller and the baker. Its action, according to Liebig, is to render insoluble gluten which has been made soluble by acetic or lactic acids developed in damp flour, and it hence stops the undue conversion of starch into dextrine or sugar. The influence of alum on health, in the small quantities in which it is usually added to bread, is very problematical, and rests upon theory more than observation. But notwithstanding the obscurity as to its action on the economy there can be no difference of opinion that it is a serious adulteration and not to be permitted.

Allen† says:

> Alum, or an equivalent preparation containing aluminium, is by far the most common mineral adulterant of bread, though its use has greatly decreased of late years. Its action in increasing the whiteness and apparent quality of inferior flour is unquestionable, though the cause of its influence has not been clearly ascertained. Whether there be sufficient foundation for the statements made respecting the injurious effects of alumed bread on the system is still an open question.

The following is from Hassall:‡

> With reference to the use of alum, Dr. Dauglish has written: "Its effect on the system is that of a topical astringent on the surface of the alimentary canal, producing constipation and deranging the process of absorption. But its action in neutralizing the efficacy of the digestive solvents is by far the most important and unquestionable. The very purpose for which it is used by the baker is the prevention of those early stages of solution which spoil the color and lightness of the bread whilst it is being prepared, and which it does most effectually; but it does more than needed, for, whilst it prevents solution at a time that is not desirable, it also continues its effects when taken into the stomach, and the consequence is that a large portion of the gluten and other valuable constituents of the flour are never properly dissolved, but pass through the alimentary canal without affording any nourishment whatever."

The manufacturers of alum baking-powders, however, claim that the hydrate of aluminium which is left in the residue is insoluble in the digestive juices, and therefore does not produce the effect which is attributed to the soluble forms of alum. Aluminium hydrate is insoluble in water, but readily soluble in dilute acids, especially when freshly precipitated. When heated it gradually loses its water of hydration, but does not part with it entirely short of a very high heat. When completely dehydrated it is insoluble even in dilute acid. It never reaches this condition in baked bread, in which the temperature probably never, in the center of the loaf at least, exceeds 100° C.

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* Foods, Composition and Analysis, p. 168.

† Commercial Organic Analysis, 1, p. 371.

‡ Food, its Adulterations, and the Methods for their Detection, p. 344.

Phosphate of aluminium is somewhat less soluble in dilute acids than the hydrate. In the Norfolk case an effort was made by the prosecution to show that the soluble phosphates contained in the ash of flour combined with the alum to form phosphate of aluminium, thus rendering them insoluble in the digestive juices and depriving the flour of an important constituent, and considerable evidence was offered by the defense to show that this was not the case. Whether the addition to alum powders of sufficient acid phosphate to combine with the aluminium present as phosphate was the result of this discussion or not I can not say, but it is certain that most of the alum powders now met with are made in this way, so that if such a prosecution were to occur to-day the relative position of the parties would be reversed. It would be to the interest of the alum-powder makers to show that phosphate of aluminium is insoluble in the alimentary canal. The solubility of these compounds in water or dilute acids is, of course, a question readily answered by any chemist, but their solubility in the complex and various alimentary fluids, and under the conditions of natural digestion in the human body, is quite another matter.

As might be expected, the testimony which has been published upon this point is of the most conflicting character. Professor Patrick, experimenting upon cats, found little or no solution of hydrate of aluminium. Professor Pitkin, experimenting with gastric juice obtained from a dog, found some solution, although he used phosphoric acid in his powder. Professor Mallet, using an artificial gastric juice, found some solution to occur, even with the phosphate, and considerably more with the hydrate. It is not difficult to find reasons for such disagreement in results, for, besides the various character of the solvents used and the different conditions prevailing, it is easy to see that even if the hydrate and phosphate of aluminium were themselves entirely insoluble, more or less aluminium would escape the reaction, either from imperfect mixing of the powder in the dough or from improper proportioning of the different ingredients in the powder itself, so that it would go into the residue in the form of the original salt. With powders specially prepared, on the other hand, and very carefully mixed, and kneaded up thoroughly with the dough, it might be possible to find but a very little dissolved in the digestive fluids under certain conditions, even though the salts formed were slightly soluble in such fluids.

From the various evidence that has been produced on both sides of the question, I think the following conclusions may be safely drawn:

(1) That form of alum powder in which sufficient phosphate is added to combine with all the aluminium present is a better form, and less apt to bring alum into the system than where alum alone is used.

(2) It must be expected that small quantities, at least, of alum will be absorbed by the digestive fluids where any form of powder containing it is used.

(3) Whether the absorption of small quantities of alum into the human system would be productive of serious effects is still an open question, and one that careful physiological experiment alone can decide.

As the experiments made by Professor Mallet are the most recent on this subject, I quote here his conclusions. I may say that most of those based upon purely chemical work I can indorse, having confirmed many in my own work, but I think the evidence furnished

by his physiological work is hardly sufficient to justify his conclusion as to the harmfulness of such powders.

GENERAL SUMMARY OF THE CONCLUSIONS REACHED.*

The main points which seem to be established by the experiments under discussion are, briefly stated, the following:

(*a*) The greater part of the alum baking-powders in the American market are made with alum, the acid phosphate of calcium, bicarbonate of sodium, and starch.

(*b*) These powders, as found in retail trade, give off very different proportions of carbonic-acid gas, and therefore require to be used in different proportion with the same quantity of flour, some of the inferior powders in largely increased amount to produce the requisite porosity in bread.

(*c*) In these powders there is generally present an excess of the alkaline ingredient, but this excess varies in amount, and there is sometimes found on the contrary an excess of acid material.

(*d*) On moistening with water these powders, even when containing an excess of alkaline material, yield small quantities of aluminium and calcium in a soluble condition.

(*e*) As a consequence of the common employment of calcium acid phosphate along with alum in the manufacture of baking-powders, these, after use in bread-making, leave at any rate most of their aluminium in the form of phosphate. When alum alone is used the phosphate is replaced by hydroxide.

(*f*) The temperature to which the interior of bread is exposed in baking does not exceed 212° F.

(*g*) At the temperature of 212° F. neither the "water of combination" of aluminium hydroxide nor the whole of the associated water of either this or the phosphate is removed in baking bread containing these substances as residues from baking-powder.

(*h*) In doses not very greatly exceeding such quantities as may be derived from bread as commonly used, aluminium hydroxide and phosphate produce (or produced in experiments upon myself) an inhibitory effect upon gastric digestion.

(*i*) This effect is probably a consequence of the fact that a part of the aluminium unites with the acid of the gastric juice and is taken up into solution, while at the same time the remainder of the aluminium hydroxide or phosphate throws down in insoluble form the organic substance constituting the peptic ferment.

(*k*) Partial precipitation in insoluble form of some of the organic matter of food may probably also be brought about by the presence of the aluminium compounds in question.

(*l*) From the general nature of the results obtained, the conclusion may fairly be deduced that not only alum itself, but the residues which its use in baking-powder leaves in bread, can not be viewed as harmless, but must be ranked as objectionable, and should be avoided when the object aimed at is the production of wholesome bread.

COMPARISON OF THE DIFFERENT CLASSES OF POWDERS IN RESPECT TO THEIR RELATIVE AERATING STRENGTH AND THE AMOUNT OF RESIDUE LEFT BY EACH.

The following comparison of the different powders described may prove interesting. It is assumed, of course, that the ingredients are combined in exactly the proper proportions, and that all the chemicals used are of full purity and strength:

Powders.	Carbonic-acid gas.	Total residue in per cent. of the weight of chemicals used.
	Per cent.	*Per cent.*
Tartrate	16	104
Phosphate	22	123
Alum	27	128
Alum and phosphate	17	111

* Chemical News, 58, 276; also published in pamphlet form.

From this it will be seen that a tartrate powder, theoretically, gives the lowest percentage of carbonic-acid gas in proportion to the weight of chemicals used in its composition, together with the least weight of residue; and a straight alum powder gives the highest proportion of gas, with the greatest weight of residue. It is assumed that burnt alum is used in both the alum and the alum-and-phosphate powders. The residues are calculated to hydrated salts in all cases. No account is made of inert "filling," as that would be the same in each case. It should of course be remembered that in the above calculation the *total weight* of residue is reckoned in each case without regard to solubility or relative effect upon the system of the various salts formed. This has been sufficiently discussed under the different classes.

CARBONATE OF AMMONIA.

This salt is used to some extent as an ingredient in baking-powders. It is also often used alone by bakers as a chemical aerating agent. It does not necessarily require an acid to set free its gases, being volatilized without decomposition simply on heating. The commercial salt, familiar to everybody as "smelling-salts," or *sal volatile*, is obtained by subliming a mixture of two parts of chalk and one part of sal ammoniac or sulphate of ammonia. The salt is then resublimed with the addition of some water, and a white semi-transparent mass is obtained, which has a strong ammoniacal smell, and a pungent, caustic taste. It has the composition $N_3H_{11}C_2O_5$, and consists of a compound of hydrogen ammonium carbonate with ammonium carbamate, $H(NH_4)CO_3 + NH_4CO_2NH_2$. "When heated the salt is wholly dissipated, without charring; if the aqueous solution is heated to near 47° C. it begins to lose carbonic-acid gas, and at 88° it begins to give off vapor of ammonia." (United States Pharmacopœia.) The question of the propriety of the use of this salt in baking does not seem to have received a great deal of attention, and opinions differ. Hassall* says of it:

> * * * Of these, by far the best is carbonate of ammonia; this is a volatile salt, and its great advantage is that it is entirely or almost entirely dissipated by the heat employed in the preparation of the bread; and thus the necessary effect is produced without risk of injurious results ensuing.

This would doubtless hold good if it were quite certain that the salt is *entirely* driven off by the baking of the bread, for it is a very active therapeutic agent, acting as a corrosive poison when taken in sufficient amount. The ordinary dose is five grains. Doubtless in the small quantities used in baking-powders, and in the presence of other chemicals, there is little danger of its being left in the bread undecomposed, but the advisability of its use alone as an aerating agent is open to grave doubt.

Of the samples analyzed in the Chemical Division the aeration strength found is expressed by the following numbers:

TARTRATE POWDERS.	Per cent.
Royal Baking-Powder	12.74
Dr. Price's Cream Baking-Powder	11.13
Cleveland's Superior Baking-Powder	12.58
"Sea Foam" (Gantz) Baking-Powder	8.03
Hecker's Perfect Baking-Powder	9.29
Gilbert S. Graves's Imperial Baking-Powder	7.28
Thurber's Best Baking-Powder	10.26
Sterling Baking-Powder	9.53
Our Best Baking-Powder, made by the Purity Chemical Works, Philadelphia, Pa	4.98

* Page 345.

PHOSPHATE POWDERS.

Wheat Baking-Powder, made by Martin Kalbfleisch's Sons, New York	3.79
Rumford Yeast-Powder	12.86
Horsford's Self-Raising Bread Preparation	13.56

ALUM POWDERS.

Vienna Baking-Powder	6.41
Metropolitan Baking-Powder	8.10
Cottage Baking-Powder	6.62

MIXED POWDERS.

Dooley's Baking-Powder	9.62
Miles's Premium Baking-Powder	3.56

ALUM AND PHOSPHATE POWDERS.

Henkel's Baking-Powder	7.74
Mason's Yeast-Powder	9.96
Dixon Yeast-Powder	10.37
Patapsco Baking-Powder	7.58
Patapsco Baking-Powder	6.70
Patapsco Baking-Powder	8.42
Silver Spoon Baking-Powder	7.33
Windsor Baking-Powder	9.36
Davis's O. K. Baking-Powder	8.10
Brunswick Baking-Powder	9.81
Atlantic and Pacific Baking-Powder	7.91
Silver King Baking-Powder	4.99
Eureka Baking-Powder	7.62
Silver Star Baking-Powder	7.61
Purity Baking-Powder	7.13

FILLING.

It is evident that of several powders made up of the same materials, the one which contains the smallest proportion of inert matter or filling, other things being equal, will have the best carbonic-acid efficiency or "strength." On the other hand, if the amount used is too small for the proper preservation of the sample, it will deteriorate rapidly, and perhaps will show less strength after keeping a short time than any other powders with a somewhat larger amount of filling. It becomes a question, therefore, as to the minimum limit of the amount of filling that is consistent with good keeping qualities. Professor Prescott* says on this point:

> From 13 to 18 per cent. of starch is not too much for the permanence of a cream of tartar baking-powder, but filling beyond 20 per cent. must be held an unquestionable dilution.

In my samples the average per cent. of starch in the bitartrate powders was 14.04; the highest was 24.57 per cent., and the lowest 5.32 per cent. The latter sample evidently did not contain enough, for it had a much lower carbonic-acid strength than most of those that had more filling. The bitartrate powder containing the maximum of filling, No. 5527, contained also the lowest per cent. of available carbonic acid. The powders made up with free tartaric acid contained much more filling, this being doubtless necessitated by the more hygroscopic character of the free acid. They contain, respectively, 40.05 and 45.63 per cent. of starch, and 9.53 and 4.98 per cent.

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* Organic Analyses, 500.

of available carbonic acid. Of the phosphate powders No. 5508 contains rather a large amount of filling, 26.41 per cent., while No. 5506 contains none at all, evidently to its detriment, as previously noted. Even the acid part of No. 5509 contains 20.81 per cent. of starch, although it is kept separate from the alkali. It is in the alum and the alum-and-phosphate powders, however, that the highest percentages of filling are found. The average of all is 40.76 per cent. of starch, the maximum 52.29 per cent., the minimum 31.54 per cent. Here we find the cause for the low percentages of available carbonic acid in these powders, which should, theoretically, afford a higher carbonic-acid strength than any of the other classes. Whether a large amount of filling is more necessary where alum is used to prevent deterioration, whether it is added simply as a diluent, so that the amount of alum taken into the stomach will be less apt to produce an injurious effect, or whether it is added to cheapen the powder, I can not say. The first hypothesis seems the most probable, especially if the alum is used with but a small proportion of its water of crystallization driven off. If the second is true, the object is not obtained, of course, for the more filling used the greater the quantity of powder required to produce the same aerating effect, and as for the third, alum and soda are about as cheap as starch.

It must be remembered that the percentages of starch given in the tables represent *anhydrous* starch.

"DOMESTIC BAKING-POWDERS."

It may be asked, can not the consumer make up his own baking-powders? The difficulties in the way of doing this may be enumerated as follows:

(1) The chemicals in the market, as purchased by the consumer, may not be pure, or of full strength, so that when combined in proper proportions they do not give good results.

(2) The proper proportions to use, and the necessity of thorough mixing to secure good results, would not be well understood by any one who was not a chemist.

(3) In order to prevent the action of the ingredients upon one another, and to preserve the strength of the powder unimpaired as long as possible, the manufacturer *dries* all his chemicals before mixing them, so as to drive off most of the adhering moisture. Baking-soda can not be dried much, as it loses its carbonic acid, and consequently its efficiency, at very low temperatures. The starch, however, containing as it does from 10 to 18 per cent. of moisture, can be thoroughly dried at 100° to 105° C., and its efficiency as a filling material greatly increased. The cream of tartar can also be thoroughly dried. This operation of drying chemicals at a temperature below that at which decomposition would occur seems rather too elaborate an operation for the kitchen.

These difficulties are more apparent than real, however. In answer to the first, it may be said that the bitartrate is the only chemical which is likely to be adulterated, and as there is no difficulty nowadays in obtaining a pure article in the wholesale market, it only requires the proper enforcement of adulteration laws to oblige the retailer to furnish a good article. The second objection may be met by furnishing the public simple formulæ for compounding such powders; and the third, which is doubtless the most serious, I believe can be overcome by using a larger proportion of filling, without drying the chemicals.

In the present days of cooking-schools, when so much interest is taken in the preparation of food, and in all branches of the culinary art, it may not be amiss to devote a little space to the discussion of this subject, although it is not, perhaps, strictly within the scope of the present investigation.

With a view of determining the possibility of making up baking-powders from a simple formula that could be used in the household, and also to see what strength of powder could be obtained by lessening the quantity of filling used, I compounded a number of powders from commercial cream of tartar and soda, using different proportions of starch, and determined the per cent. of carbonic acid, both total and available, in each. The chemicals used were dried before mixing, and the latter operation very thoroughly performed.

Formula No. 1, containing 20 per cent. starch filling.

Cream of tartar	ounces	8
Baking-soda	do	4
Corn starch	do	3
Total carbonic acid	per cent.	13.39
Available carbonic acid	do	11.96

Formula No. 2, containing about 15 per cent. starch filling.

Cream of tartar	ounces	8
Baking-soda	do	4
Corn starch	do	2
Total carbonic acid	per cent.	14.60
Available carbonic acid	do	12.89

Formula No. 3, containing 10 per cent. starch filling.

Cream of tartar	ounces	6
Baking-soda	do	3
Corn starch	do	1
Total carbonic acid	per cent.	15.10
Available carbonic acid	do	13.70

From the above it will be seen that most excellent results were obtained with these powders, made up by simple formulæ. The powder containing the least percentage of starch, formula No. 3, gave 13.70 per cent. of available carbonic acid, nearly 1 per cent. more than the highest result obtained in any of the commercial samples. To be sure these powders were freshly made, and would doubtless deteriorate on keeping, those with the lowest amount of starch perhaps more rapidly than the others, as most of the commercial samples containing less than 10 per cent. of starch show low percentages of available carbonic acid, No. 5505 being an exception. But these prepared samples establish very completely the point I desired to make, that baking-powders can be readily made up by simple formulæ that will compare favorably with the best samples obtainable in the market.

These samples, however, were all made with *well-dried* ingredients, as they would be by a manufacturer. The next question is, whether a powder could be made which would keep without serious deterio-

ration, without drying the chemicals. To this end I used a larger proportion of starch according to the following formula:

Formula No. 4, made without drying the ingredients, containing 25 per cent. starch filling.

Cream of tartar	ounces..	8
Baking-soda	do....	4
Corn starch	do....	4
Total carbonic acid	per cent..	12.63
Available carbonic acid	do....	10.91

This gives a fairly good amount of available gas, considerably higher than the average of the commercial samples. Estimations of the available carbonic acid in the same sample after it had stood over two months in the laboratory showed absolutely no loss in strength. I had it tried in a practical way by several persons in the Department who used it in their kitchens, and reported excellent results, finding it fully as efficient in all respects as the powder they were accustomed to buy. The consumer can pay full retail price for the ingredients and still make it up for about half the price at which a good powder is sold, and if he makes sure of the quality of his cream of tartar he will have an article of which the purity is assured, and which has not lost in strength by being kept in stock an indefinite length of time by the retailer. I can see no reason why all housekeepers should not make their own baking-powder.

REGULATION OF THE SALE OF BAKING-POWDERS.

The best plan for the regulation by law of the sale of baking-powders in the present condition of our knowledge of their effect upon the system would seem to be to require the manufacturer to use a label giving approximately the composition, or analysis, of the powder sold. This is recommended by Professor Cornwall, and it appears to offer the best solution of the whole problem. The testimony that has been adduced is hardly sufficient to justify the prohibition of the sale of the cheaper kinds of powders as being injurious to health, but if they were required to be sold with a label giving their true composition it would soon lead to investigations upon this point. This is in harmony, also, with modern ideas in regard to legal regulation of the sale of food-stuffs, the tendency nowadays being to allow the sale of cheap substitutes for any article of food so long as they are not actually injurious to health, but to make all possible provision to insure that the purchaser should know exactly what he is getting, and that the substitute shall not be palmed off on him as the genuine article. In the case of baking-powders it is manifestly unjust to the public to allow the sale of a first-class tartrate powder and an alum powder as the same article, and it is equally unjust to the manufacturer of the higher-priced article. The nature of the substance is such that the purchaser has no means of ascertaining by any simple or easy means the character of the article he buys, to say nothing of its relative quality. Such a regulation should meet with the approbation of all concerned in the manufacture of baking-powders. The manufacturers of high-grade powders, such as tartrate or phosphate powders, would certainly not object to it, and it would ultimately be to the advantage also of the cheaper sorts, such as alum powders, provided they could succeed in proving that such powders produced little or no injury to the health of the consumer.

Ample analogy and precedent for such regulation are furnished

by the laws for the sale of fertilizers which are in operation in most of the States. Although these substances are used for widely different purposes, the conditions that require the legal supervision of their sale are quite similar in many respects. A substance sold as a fertilizer must have its composition, in so far as is necessary for its valuation for such a purpose, plainly stated on the bag in which it is sold, because the purchaser has no means of ascertaining this value by any ordinary or simple test. Otherwise the manufacturer could easily impose upon him by selling him a powdered substance which resembled a fertilizer in general appearance, but contained no constituent of any value whatever for fertilizing purposes. The purchaser of a baking-powder receives a white powder which may contain various substances more or less valuable for the desired purpose, or of no value whatever, or perhaps even injurious to the health.

The housewife surely deserves protection against swindling as much as the farmer, and she has no better means for ascertaining the strength and quality of the baking-powder she buys than the latter has for learning the strength of his fertilizer. The verity and accuracy of the analysis stated on the label should be insured, as in the case of the fertilizer, by its being performed by sworn analysts. If such a regulation were enforced, people would soon inform themselves of the respective merits of different varieties, and the further requirement of a certain standard of strength, as suggested by Professor Cornwall, would probably be unnecessary, as they would learn to interpret the analysis, and a powder made up with 50 per cent. of starch, for instance, would have to be sold cheaper than one made with 10 per cent., or not sold at all.

INFLUENCE OF FOOD, ANIMAL IDIOSYNCRACY, AND BREED ON THE COMPOSITION OF BUTTER.

One of the fundamental principles of dairying is regard for the influence which the care of the animal, supervision of the milking, separation of the cream, ripening of the cream, churning and washing, have on the quality of butter for table use. These processes also, together with the method of packing, have a notable influence upon the preservation of the butter in a sweet state. The discussion of the above problems, however, is a thing for the practical dairyman rather than the chemist. The chemical composition of butter fat, as influenced by the character of food received by the animal, the race of the animal, and the peculiarities of the animal, has hitherto been little studied from a chemical point of view. To the latter subject I propose to devote the following paper.

Late in February, this year, I received a letter from Prof. H. H. Harrington, chemist of the Experimental Station of Texas, accompanied by two samples of butter which he asked me to examine. The following extract from Professor Harrington's letter will indicate the motive which led him to send samples:

> Some work in our laboratory indicates that volatile acids from the cotton-seed butter are much lower than has been generally supposed. I send two samples of butter, one from cotton-seed feed and the other from feed containing no cotton-seed. If you can do me the favor of analyzing this butter, I shall send more samples from the same cows on the same feed. We hope in the near future to follow up these analyses with complete analyses of butter from different feeds, feeding two cows on cotton-seed and then changing them to other feed.

The two samples of butter received from Mr. Harrington were entered as follows: Butter from cotton-seed No. 6316; butter from other feed, No. 6317.

The samples sent by Mr. Harrington were small and a complete analysis could not be made; but the results obtained on the small samples sent are of such interest that I will communicate them at the present time and call attention to the peculiarities noticed.

Results of analyses.

[Degrees Centigrade.]

	Volatile acids $\frac{N}{10}$ BaO_2H_2 for 5 grams.	Iodine absorbed.	Melting point.	Reduction of silver by Bechi.
	Cc.	*Per cent.*	°	
6316	21 00	33.40	45	Distinct.
6317	28.50	31.89	34.2	None.

The most remarkable points connected with the above analyses are as follows:

(1) The low percentage of volatile acids in butter from cotton-seed.
(2) The phenomenally high melting point of the butter from cotton-seed.
(3) The persistence of the reducing agent of the butter from cotton-seed as indicated by its action upon nitrate of silver.

The melting point of the butter, as will be seen, is higher than that of pure lard. The particular point to be noticed in this matter is that in butter designed for consumption in southern countries, or produced in southern countries, the mixture of cotton-seed with the feed of cows will tend to raise the melting point of the butter and render it more suitable for consumption in hot climates.

The persistence of the reducing agent is also a matter of interest. It has passed, in the samples examined, through the digestive organism of the cow and has re-appeared in the butter with almost undiminished activity. The selective action of the digestive organs on the different glycerides contained in the food of the animal is also a matter of importance. It would be expected *a priori* that the butter from a cow fed largely on cotton-seed oil would contain more olein and have a lower melting point than if ordinary food were used. On the contrary it is seen that either the more solid glycerides have been absorbed during the process of digestion or that the olein has undergone some distinct change in the digestive organism by which it has assimilated the qualities of the other glycerides.

From an analytical point of view the results are of great importance, since they show that a butter derived from a cow fed on cotton-seed meal or one excreting a fat of unusual quality might be condemned as adulterated when judged alone by the amount of volatile acids present. Since cotton-seed meal is destined to be a cattle food of great importance, especially in the southern part of the United States, this is a fact of the greatest interest to analysts.

The observation of Mayer, soon to be mentioned, that the specific gravity of butter fat varies with its content of volatile acids, I have also verified in some cases by the determination of the specific gravity of samples of butter fat taken from the milk of the same cows kept on the same food, but taken the following day after the samples mentioned.

The specific gravity for the cotton meal fed sample was .8929 at 99°; the specific gravity for the ordinary fed sample was .8991 at 99°.

Professor Mayer's experiments were made on a single cow of a North Holland breed. From time to time during the progress of the experiments the original food was used in order to see what effect the period of lactation would produce. The cow was fed for twelve days on each separate ration before the samples were taken. After two days more another set of samples was taken, and then the food changed for a new experiment.

In the butter fat the melting and solidifying points were taken and the volatile acids determined according to the method of Reichert. The specific gravity was also determined by the Westphal method at 100°.

The rations of the cow were composed of the following materials:

Ration No. 1. 15 kilograms meadow hay and 2 kilograms linseed cake.

Ration No. 2. Siloed grass *ad libitum*, and 2 kilograms linseed cake.

Ration No. 3. 20 kilograms beets, 8 kilograms hay, and 2 kilograms linseed cake.

Ration No. 4. Pasture grass *ad libitum*.

Ration No. 5. Chopped clover with 14 per cent. of other grasses *ad libitum*.

The highest melting point observed (viz, 40.5) was from ration No. 1, and the lowest (viz, 32.5) from ration No. 5. The highest volatile acids were produced by No. 3, and required 33.5 cubic centimeters $\frac{N}{10}$ alkali. The lowest volatile acids, viz, 20 cubic centimeters, were observed with ration No. 2.

The results of my analyses were obtained on the first samples of butter sent by Mr. Harrington, and were published in Agricultural Science for April 1, 1889, pp. 80 *et seq*. Not fully satisfied with the result of a single determination, I asked Professor Harrington to send me other samples of butter, which he did on two subsequent occasions. The analyses of the two last sets of samples sent did not fully bear out the results obtained in the first set. This led me to believe that perhaps the influence of the animal was not fully allowed for in Professor Harrington's samples. The last two sets of samples were analyzed with the following results:

No. 6347, sample from cow fed on corn meal and wheat bran only.

Nos. 6348, 6349, and 6350 from cows fed on 2 pounds cotton-seed meal, 4 pounds cotton-seed, and 16 pounds corn and wheat bran.

No. 6374, from cow having no cotton-seed in food.

Nos. 6375, 6376, and 6378, from cows fed solely on cotton-seed meal.

The analytical data obtained are as follows:

	Specific gravity at 100° C.	Volatile acid $\frac{N}{10}$ alkali.	Melting point.
	°	*Cc.*	°
6347	....	24.70	35.10
6348	*.9063	27.50	40.60
6349	.9009	27.70	40.30
6350	.9009	25.30	40.30
6374	.8967	19.95	36.90
6375	.8989	27.20	34.45
6376	.8962	25.80	36.60
6378	.8989	25.40	36.23

*This number is probably too high.

The above data are very perplexing. The conclusions derived from the first set of samples are supported solely from the fact that the cows fed on cotton-seed meal gave butters which, with one exception, had a higher melting point than ordinary butter. The phenomenally low percentage of volatile acids in 6374 would indicate that the cow furnishing this sample was the same as that furnishing the low volatile acids in the first set of samples. An inquiry directed to Professor Harrington to elucidate this point, however, has not yet been answered, Mr. Harrington replying that he has not had time to inform me on the subject.

Another supposition is that in some way the numbers of the samples may have been changed in the analysis, but this is scarcely probable. The importance of a more careful study of this subject led me to institute some feeding experiments of my own in order to unravel, if possible, the mysteries of the preceding analyses. I accordingly obtained authority from the Secretary of Agriculture to arrange for certain feeding experiments with Professor Alvord, of the Maryland Agricultural Experiment Station. Three cows were selected for these experiments, described by Professor Alvord as follows:

No. 1. Full-bred Jersey.
No. 2. Full-bred Ayrshire.
No. 3. Cross-bred Jersey and Ayrshire.

These cows were kept on ordinary pasturage for ten days, and then the milk from each of the cows for three days was taken for the experiments. All the milk was subjected to the same conditions. It was set in earthen bowls in a refrigerator, at 45° to 50° Fah., and skimmed after twelve hours. The cream was mixed and kept at 55° to 60° Fah. until the fourth day after the beginning of the milkings. The cream was then ripened in a room, at 60° Fah. temperature, for twenty-four hours. After cooling to 62° Fah., the cream was churned, the temperature rising from 62° Fah., at the beginning of the churning, to 65° at its close. The time required for each churning was twenty minutes. The three days on which the milk was saved were damp, hot days, very unfavorable for making good butter. In all cases the butter was thoroughly washed in cool well-water, made into rolls, and put in glass jars. One-half of each sample of the first lot was salted at the rate of two-thirds of an ounce of salt to 1 pound of butter.

After the conclusion of the first set of experiments the cows were gradually changed to a ration of cotton-seed meal, using the commercial variety, such as is used for fertilizing purposes, as no unextracted cotton-seed meal could be obtained at this season of the year. The ration of cotton-seed meal was gradually increased, the cows finally being given all they would eat of it. The following are the facts as to the second lots:

The feeding of cotton-seed meal was commenced on the 25th of July, giving but 1 pound at a feed at first, but constantly increasing the quantity. The milk saved and used for the second lots of butter was that of the 2d, 3d, and 4th of August. Below is given a table showing the quantity of meal consumed; milk, cream, and butter produced from each cow, and time of churning:

Lot.	Breed.	Cotton-seed meal consumed on August 1, 2, and 3.	Milk product used for the butter August 2, 3, and 4.	Cream from the milk stated churned.	Butter made from the stated cream August 6.	Time of churning for each lot.	Temperature of cream at starting churn.
		Lbs.	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Min.*	°
1	Jersey	28	32 15	16 8	2 05	13	62
2	Ayrshire	32	37 00	9 12	1 12	22	62
3	Cross-bred Jersey and Ayrshire	29	32 04	9 0	1 07	14	63

During this trial the cows were turned into a small lot with very short pasturage, for exercise and access to running water.

They were fed only the cotton-seed meal and consumed the quantity stated. At close of trial the Jersey and cross-bred cows were beginning to refuse the meal. The Ayrshire continued to eat all offered and probably could have been fed 12 pounds a day—but I was afraid to give her over 11 pounds a day and did that only twice. (She later kept on at 8 and 10 pounds per day, while the others fell to 1 and 2 pounds.)

The analytical data obtained on these samples of butter are found in the following table:

DESCRIPTION OF SAMPLES.

6467, unsalted butter from pure Jersey cow on pasture, no feed.
6468, unsalted butter from pure Ayrshire cow on pasture, no feed.
6469, unsalted butter from cross-bred Jersey and Ayrshire on pasture, no feed.
6470, salted butter, same as 6467.
6471, salted butter, same as 6468.
6472, salted butter, same as 6469.
6478, butter from pure Jersey cow fed on cotton-seed meal.
6479, butter from pure Ayrshire cow fed on cotton-seed meal.
6480, butter from cross-bred Jersey and Ayrshire fed on cotton-seed meal.

In addition to the above samples I have also included two samples of creamery butter from a large creamery at Attica, Kans.

Eight thousand pounds of milk are received daily at this creamery, all of which comes from native cows feeding on native prairie grass, with the exception of a few Holstein cows kept by one person.

6409, butter from Attica Creamery, made May 20, 1889.
6473, butter from Attica Creamery, made July 20, 1889.

Table of analyses.

[Degrees centigrade.]

Serial No.	Melting point.	Iodine absorbed.	Volatile acids $\frac{N}{10}$ BaO_2H_2 for 5 grams.	Specific gravity.	Bechi's reaction.	Milliau's reaction.	Fatty acids.	
							Crystallizing point.	Iodine absorption.
	°	*Per cent.*	*C. c.*				°	*Per cent.*
6467	34.9	37.7	22.8	.9010	None.	None.	38.95	38.69
6468	36.3	41.1	22.5	.9005	None.	None.	39.80	42.50
6469	35.2	38.0	22.1	.9019	None.	None.	38.55	39.20
6470	35.3	37.9	22.3	....	....	....	....	....
6471	35.6	40.7	22.5	....	....	....	....	....
6472	35.2	38.2	22.3	....	....	....	....	....
6478	38.4	34.9	21.4	.9016	Marked.	Marked.	41.25	37.96
6479	49.0	36.8	20.8	.9012	Marked.	Marked.	43.30	38.72
6480	38.3	35.2	21.1	.9011	Marked.	Marked.	41.45	37.63
6409	33.3	....	28.1	.9001	....	....	....	....
6473	34.4	29.8	20.3	.9021	Trace.	Trace.	39.60	31.26

The study of the data in the above table reveals many points of interest. In general the data corroborate the results of the first study of the samples sent by Professor Harrington. The melting points of the butters from cows fed on cotton-seed meal are markedly higher than from the other samples. There is also a markedly diminished content of volatile acids in these butters and a lower iodine absorption power. The latter character is unlike the Harrington sample. Another characteristic phenomenon noticed in the first samples of butter is also here repeated, namely, the persistence of the reducing agent which is present in cotton-seed oil in the butter derived from animals fed thereon. The physiological importance of this phenomenon will be mentioned in another place. The most curious results, however, of these experiments is found in the increase in the butter of the glycerides having a high melting point; in other words, the glycerides of the palmitic and stearic series. While further experiment may be necessary to show that there is a uniform diminution of volatile acids in butters from cows fed on cotton-seed meal, the fact is now most clearly established that the melting point of such butters is uniformly higher. In regard to the absorption of iodine by the butters from cotton-seed fed cows, the results obtained above are somewhat at variance with those secured by Ladd,* who states that butter from cows fed on linseed meal contained 3.5 per cent. more olein than those samples which were obtained from cows fed on bran. This conclusion of Ladd's, however, may not be the true one, since linseed oil has an iodine absorption of about 155 per cent., and this high co-efficient may have had some influence upon the butter as regards iodine absorption. It is possible, therefore, that some of the linoleic glyceride, which has so high an iodine absorbing power, may have found its way into the butter, thus increasing its iodine absorption.

Another important characteristic of the butters examined is seen in their abnormally low content of volatile acids. If we compare the samples from the Maryland station with those from Kansas, we have a very characteristic contrast between abnormal pure butter and normal pure butter. The two samples from Kansas show a percentage of volatile acids which is not unusually met with in samples of pure butter. On the other hand, the samples from the Maryland station show an abnormally low content of volatile acids. This percentage of volatile acids is indeed so low that these butters would be condemned as spurious if we relied upon the volatile acid test alone. It does not seem so strange in the light of these facts that Allen should have found abnormal Danish butters which, nevertheless, from their history, were certainly genuine.

In so far as the breed of the animal is concerned in the above experiments, it does not seem to have greatly influenced the composition of the butter. The low content of volatile acids may therefore be attributed either to the pasturage or to the peculiarity of the animals themselves, or to the period of lactation.† It would hardly seem probable, however, that three animals taken at random should have

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* Report of New York Experiment Station for 1888, page 91.

† The time at which each of the cows in the above experiments commenced giving milk is as follows: Jersey cow, February 3, 1889; Ayrshire cow, March 23, 1889; cross-bred Jersey Ayrshire, April 15, 1889. The period of lactation therefore was not far enough advanced, the experiments having been made in July, 1889, to have accounted for the abnormal character of the butter obtained.

exhibited in almost the same degree the abnormal qualities indicated in the composition of the butters above.

The physiological questions which are suggested by the above study are of the utmost consequence. In a paper entitled "Note on the action of digestive fluids on oil," published in The Medical News of July 28, 1888, I called attention to the remarkable influence exerted on a large quantity of oil in the human digestive organs. A pint of oil, presumably sweet oil, but more likely cotton oil, was administered to the patient for the relief of an obstruction in the gall duct. This oil in passing through the digestive organs was completely decomposed mostly into fatty acid with some soap, forming an emulsion in the alimentary canal, and being voided in the form of rounded masses of considerable consistence were mistaken by the patient for gall stones. This action of the digestive liquids was entirely unexpected and seems to show that the commonly accepted notion that the fats are acted upon in the digestive organs by being emulsified and thus absorbed into the circulatory fluids is an erroneous one.

It is the common supposition that the fats have for a physiological function the maintenance of the animal heat of the body and the nutrition and supply of the fatty portions thereof.

The experiments in feeding cows on cotton-seed meal would seem to indicate that the natural glycerides contained in cotton-seed meal do not appear in the butter of the cows fed thereon. If the cotton-seed oil in the food should pass unchanged into the butter, we might, it is true, have a lowering of the volatile acids, but this would be accompanied by a great increase in the iodine absorption and a marked lowering in the melting point. It is quite certain that the glycerides of butter which yield on saponification volatile acids are not derived from similar glycerides in the food of the animal. It may also be quite true that none of the glycerides in the butter of the cow is derived from the fat of the food of the animal. It is more than likely that the fat of milk is a direct product of digestion and is formed conjointly from the carbohydrates and the albuminoids in the cow's food. We need not, therefore, be perplexed any longer at the presence of so small a portion of stearine and so large a proportion of the butyric series of the glycerides in the fat of milk.

From the evidence already at hand, I think we would be justified in saying that practically all the fats in milk are products of digestion and none of them results of simple translation through the digestive organs or fats already present in food. On the other hand we have undoubted evidence of the translation of other substances directly from the food of the cow to the butter fat, as is shown in the presence of the aldehyd in cotton oil, which reduces silver, in the butter of cows fed on these substances. Among other studies on the influence of the food on the composition of butter I might cite the paper of Ladd, already noted, and also one by C. J. von Lookeren, published in the Milch Zeitung, No. 3, 1889, page 47, and the paper of Mayer, published in Die Landwirtschaftlichen Versuchs-Stationen," vol. 35, page 261. These studies are of such practical interest that it is my intention to continue them during the coming year on an extended series of feeding experiments, in which I hope to interest experimenters in different parts of the country.

COMPOSITION OF BUTTERS SENT BY PROF. G. E. MORROW FROM THE CHICAGO DAIRY SHOW, DECEMBER, 1889.

These butters presumably represent first-class articles and analyses are interesting in showing what the composition of pure butter should be. In the following table will be found the analysis of each sample. The means may be taken to represent fairly well the composition of a first-class article of butter.

[Degrees centigrade.]

No. of sample.	In the filtered fat. Refraction index at 30°; water at same temperature equals 1.3321.	Specific gravity compared with water at boiling point.	Melting point.	Iodine absorbed.	Volatile acids per 5 grams BaO_2H_2, in cc. BaO_2H_2.	In the butter. Moisture.	Salt and ash.	Curd.
			°	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
*750 †6583	1.4579	.90120	31.8	36.9	25.5	8.69	4.58	0.86
*751 †6582	1.4569	.90173	32.4	32.4	27.7	10.47	2.52	1.13
*752 †6581	1.4571	.90026	32.2	32.1	27.9	9.52	3.40	1.01
*762 †6586	1.4565	.90294	32.8	31.9	Not determined	8.87	2.13	0.74
*764 †6587	1.4573	.90059	32.9	38.4	25.2	8.85	3.35	0.49
*765 †6589	1.4570	.89982	32.2	32.5	27.4	9.82	2.69	0.89
*766 †6588	1.4571	.90069	32.5	35.4	27.5	9.78	2.06	0.72
*767 †6585	1.4565	.90091	32.8	32.1	27.2	11.86	1.77	1.20
*770 †6584	1.4572	.90023	32.8	34.1	28.6	8.95	3.11	1.04
Means.	1.4569	.90093	32.5	34.0	27.1	9.65	3.00	0.84

* Chicago number. † Serial number.

COMPOSITION OF LARDS SENT BY HON. W. J. IVES, DAIRY COMMISSIONER OF MINNESOTA.

Five samples of lard were sent to the Department for examination by the Hon. W. J. Ives, dairy commissioner of Minnesota. From the examination which they received in Minnesota it was thought that they might be adulterated with cotton oil. There was not a sufficient quantity of the samples for making a complete examination, but the analyses were extended as far as the amount of material would permit. The analytical data obtained are found in the following table:

[Degrees centigrade.]

No. of sample.	In the filtered fat. Refraction index at 30°; water at same temperature equals 1.3321.	Specific gravity compared with water at boiling point.	Melting point.	Iodine absorbed.	Rise of temperature with H_2SO_4.
			°	*Per cent.*	°
6590	1,4621	.89472	39.2	58.3	39.0
6591	1,4624	.89643	38.2	60.7	40.0
6592	1,4618	.89488	38.8	59.5	35.5
6593	1,4618	.89500	38.8	59.9	35.0
6594	1,4618	.89567	38.2	59.0	35.0
6595	1,4622	.89533	40.2	60.4	38.0

The lards were also examined with nitrate of silver but no reduction of the silver could be secured which would indicate the presence of any notable portion of cotton oil. The quantity of the material at my disposal did not permit a complete examination of the samples for color reaction with sulphuric and nitric acids, but in so far as the test was applied no certain indication of cotton oil was detected.

The microscopical examination of the crystallized fats showed some indication of the presence of beef-fat crystals, but the proof was not definite. In all respects the samples deported themselves like pure lard and they could not be condemned as spurious without more extensive and thorough examination.

THE FOOD VALUE OF SORGHUM SEED.

For many years the value of sorghum seed as food for animals has been recognized, and it has been extensively used, especially for feeding swine. The chief objection to its use has been on the supposition that it contained tannin, or some bitter principle, which would prove injurious to stock. A careful examination of sorghum seed has failed to discover the presence of tannin, and the only possible injurious principle which it can contain is the coloring matter of the glumes. A careful examination of this coloring matter has been made and its composition determined. It consists of 33.5 per cent. of carbon, 6.6 per cent. of hydrogen, 7.2 per cent. of nitrogen, and 52.5 per cent. of oxygen. Any possible ill effects of this coloring matter, when seed is used for food, can be removed by the removal of the glumes, which would not be a difficult mechanical process. Compared with maize and oats, the seed itself is shown to be of fair quality, equal in food value to either of the other substances named. Analyses were made of a great many different varieties of seed, but the chief difference in the varieties is shown in the percentage of coloring matter rather than in the composition of the seed itself. If sorghum should be raised for seed alone, those varieties producing a pure white seed, like the White Mammoth, should be preferred to those producing highly colored seeds, like the Early Amber and most of the varieties of Chinese cane. The percentage of moisture in sorghum seed is about 10, the actual percentage found being 9.59 as a mean of 48 analyses. The percentage of albuminoids was found to be 11.71; of fat, 3.35; of substances soluble in ether, 0.50 per cent.; the soluble carbohydrates, 3.37 per cent.; the percentage of ash, 1.70; of indigestible fiber, 1.89 per cent.; the percentage of starch and insoluble digestible carbohydrates was 68.03. These analyses will compare favorably, in regard to the food value, with those of maize. The above analyses were based on the seeds from which the glumes had been removed.

The value of sorghum seed, as a food for man and other animals, is found to be fully equal to maize and oats and but little inferior to wheat. When fed, excepting to poultry, the seed should be either ground or boiled, otherwise much of it will pass the digestive organs untouched.

ANALYSES OF WHEAT AND BARLEY.

Four samples of wheat from Weiser, Idaho, sent by V. D. Hannah, accompanied by the following letter:

WEISER, IDAHO, *February* 14, 1889.

DEAR SIR: Inclosed find samples of four varieties of wheat, which I think it hard to beat. Last season was the worst ever seen since the settlement of Idaho. We are always glad to try anything new. This bearded sample came from you, and we raised last season at the rate of 70 bushels per acre. I prize it very highly.

Very respectfully,

V. D. HANNAH.

COMMISSIONER OF AGRICULTURE.

The samples were analyzed with the following results:

Serial No. 6450, short, heavily bearded head.
Serial No. 6451, short head without beard.
Serial No. 6452, short, rugged, but unbearded head.
Serial No. 6453, long, unbearded head.

	Serial No.				Average.
	6450.	6451.	6452.	6453.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	14.55	12.59	14.04	12.85	13.51
Ash	3.00	2.30	2.58	2.31	2.55
Fat	2.45	2.25	2.00	2.25	2.24
Fiber	1.20	1.40	1.48	1.16	1.31
Albuminoids	14.35	11.20	12.51	12.34	12.60
Carbohydrates (difference)	64.45	70.26	63.39	69.09	67.79
	100.00	100.00	100.00	100.00	100.00
Weight of 100 grains ..... Grams	3.160	3.360	3.405	3.000	3.231

These samples show a very high percentage of albuminoids in 6450, a rather low percentage in 6451, and a mean percentage in the other two samples.

From W. H. P. Trudgeon, Purcell, Ind. T., a sample of wheat which had the following composition:

Serial No. 6385.

	Per cent.
Water	13.27
Ash	1.88
Fat	2.31
Crude fiber	1.90
Albuminoids	13.12
Carbohydrates (by difference)	67.52

From D. H. Talbot, Sioux City, Iowa, a sample of barley, which had the following composition:

	Per cent.
Water	12.03
Ash	2.19
Fat	2.40
Crude fiber	1.58
Albuminoids	15.93
Carbohydrates (by difference)	65.87

From T. J. Wrampelmeier, San Diego, Cal., a sample of wheat, which, on examination, gave the following results:

	Per cent.
Water	11.56
Ash	1.90
Fat	2.42
Crude fiber	1.76
Albuminoids	11.03
Carbohydrates (by difference)	71.33